THE SCIENTIFIC MONTHLY

THE SCIENTI MONTHLY

EDITED BY J. McKEEN CATTELL

VOLUME XIX
JULY TO DECEMBER, 1924

NEW YORK
THE SCIENCE PRESS
1924

THE SCIENCE PRESS PRINTING COMPANY
LANCASTER, PA.

THE SCIENTIFIC MONTHLY

JULY, 1924

THE MASTER KEY

By Dr. PAUL R. HEYL

BUREAU OF STANDARDS

Some time ago an interesting question was raised in conversation among a group of members of the Bureau of Standards. Scientific men are engaged in studies which lead over a wide range, from the very small to the very large; and the question raised was this: In which direction, toward the infinitely small or toward the infinitely great, are we most likely to find the master key to the riddles of the universe?

Some difference of opinion existed among the members of the group as to the answer. I have since asked the same question of a number of other persons, and have encountered a like divergence of view. It is to be said, however, that the majority favor the infinitely small; it is in the microcosm rather than in the macrocosm that most persons believe the best chance of success to lie. Yet the advocates of the other view are by no means lukewarm in its support, or at a loss for arguments in its favor. One upholder of the infinitely large said that he did not see how it was possible for any one to hold the opposite view; and the champions of the microcosm are, I believe, sometimes so enthusiastic as to hold a similar but opposite opinion.

Though doctors disagree in this way, it may yet be profitable for us to spend a little time in the consideration of the matter; for it is in the contemplation of such subjects that we best can develop and extend our sense of perspective. The necessity for specialization that more and more is laid upon all scientific workers carries with it the danger of an increasing narrowness of view. One of the most delightful as well as valuable traits of the earlier investigators of nature was their breadth of vision, their catholicity of interest. With a view that could and did comprise all that was

then known of the physical facts of nature they saw suggestions and hints of relationship which might perhaps long escape the eye of the modern specialist.

It was not an accident that it was the many-sided Franklin who first demonstrated the identity of lightning and electricity; and it was no whim or waywardness of fate that the once seen, never forgotten parallel between gravitation and inertia should have remained hidden from seven generations of diligent investigators to be revealed to one who had never been known as an experimental investigator at all, but who had the breadth of vision to formulate an induction based upon the apparently fruitless experiments of others whose sense of perspective did not disclose to them the true value and interrelation of their negative results.

You have all seen those puzzle pictures in which, we are told, are concealed certain figures, the outline of an animal or of a human face. Though the outline may long elude detection, when once seen it is so plain that we wonder how any one could help seeing it immediately. Sometimes the difficulty in finding the figure is due to a too minute examination of detail; often only by standing off and regarding the general effect is the outline to be discovered.

A good example of how the correlation of large and small scale experimental studies may be fruitful of results, where either alone is imperfect and unsatisfactory, is furnished by the history of the determination of speed of light. The first recorded experiment of this kind was made by Galileo, using lantern signals over a distance of two or three miles. Of course, this failed completely. By a long range research, however, he discovered the moons of Jupiter, which later enabled Römer to make the first determination of this important physical constant.

Still later, the discovery of the aberration of light by Bradley, taken in connection with the then roughly known size of the earth's orbit, gave an independent measure of the velocity of light. As a result, there was perceptible a patronizing tendency on the part of astronomers toward physicists. Said the astronomers: "You students of nature on the small scale are fine fellows for the most part; but when it comes to the measurement of such a distinctively physical constant as the speed of light you have to come out into our laboratory to do it."

It was a century and a half before the physicist could find an answer. Finally, the speed of light was measured over terrestrial distances, and so rapidly did method and technique improve that astronomers were forced to correct their estimate of the distance from the earth to the sun by means of this newly determined value

of the speed of light. The physicists then had, as they thought, the last laugh. Fortunately for the astronomers, one of the fraternity discovered in 1898 a remarkable and unique asteroid, which approaches the earth more closely than any other heavenly body except the moon. By observations on this planet (Eros) the distance of the sun from the earth was determined with an accuracy which exceeds that of the velocity-aberration method by a small margin.

And so the matter stands to-day. Astronomers and physicists have learned to respect each other, and from this league of scientific nations has sprung the fruitful science of astro-physics.

But the workers in the small scale to-day are *par excellence* the students of atomic structure and radioactivity; and it is doubtless the flood of light which these researches have thrown upon the constitution of matter which has caused most persons to look favorably in this direction for the master key to the closed doors of the universe. So fruitful of results has been this study of the infinitely small that it has overflowed its banks, and made important contributions toward the solution of such large scale problems as the age of the earth, the geological cycles of continental elevation and depression and the source of the sun's heat.

In the study of radioactivity we have learned to measure the rate of decay of uranium, and have found the final product of its transformation to be lead—lead which can not be distinguished chemically from ordinary lead, but which shows a measurable difference in atomic weight. Certain uranium minerals containing lead have been analyzed, and the ratio of lead to uranium determined. The lead has also been extracted from the mineral and its atomic weight ascertained, indicating how much of it has resulted from radioactive decay. As a result, it appears that the rock in question is at least 900 million years old.[1]

Geology teaches us that large areas of what is now land were at one time beneath the sea, and, conversely, that land connections formerly existed between England and France; between Europe and Africa at Gibraltar and at Sicily; and between Asia and Australia. There is evidence that similar elevations and depressions have taken place repeatedly in a cycle with a period of millions of years. Joly[2] has lately offered an explanation of this cycle based upon the radioactivity of the rocks of the earth's crust. Assuming the lower basaltic strata to contain the same percentage of radioactive material as is found in those basaltic rocks available for examination at the surface, he finds that the heat developed

[1] Duane, Proc. Am. Phil. Soc., Vol. 61, p. 286, 1922.

[2] Joly, *Phil. Mag.*, Vol. 46, p. 1167, 1923.

in the lower layers is greater than that actually being carried off by conduction in the upper layers. In consequence, the lower strata must eventually melt, and suffer a diminution in density. But because the melted rock makes better thermal contact with the overlying strata than did the solid form, and also because the melted rock is a better conductor (or rather convector) of heat than the solid form, it will now lose heat more rapidly than before, cool and solidify with an increase of density, cracking loose from the surface layers, and again making poor thermal contact. The cycle then begins over again. In consequence of this periodic alteration in density of the underlying strata, the balance or isostasy of continents and oceans is disturbed, and elevations and depressions are produced. For this cycle Joly assigns a period of 40 million years.

Various theories have been advanced as to the source of the heat energy which the sun is expending so lavishly. The contraction theory of Helmholtz[3] was for a long time the best explanation that had been found, but it was never completely satisfactory. Helmholtz regarded the sun as having originated from the contraction, under its own gravitation, of a widely diffused nebula, the potential energy of separation of the parts of the nebula reappearing in the condensed form as heat energy. Helmholtz calculated that a contraction in the present diameter of the sun at a rate so slow that it would require a thousand years to become perceptible to us would account for the present output of solar energy. Carrying the calculation back into the past, he showed that it was possible in this way to account for the present rate of solar expenditure over a period of from 20 to 30 million years. Here lies one of the weak points of the theory, for all evidence points to an age of earth history far exceeding this paltry estimate.

It has been suggested that the sun, like the earth, contains radioactive matter, and that his heat is largely maintained from this source. While no one has as yet detected radioactive substances in the spectrum of the sun, there is abundant evidence of helium, which is known to be a product of radioactive decay and our knowledge of the sun's chemical composition is, of course, confined to his outer layer. The proportion of radioactive material necessary on this hypothesis, while greater than that found in the crust of the earth, is not excessive. Calculating it as radium, two or three parts by weight in a million would suffice.[4] It is more than possible that this may be the principal term in the explanation of the solar energy.

[3] Helmholtz, Popular lecture at Königsberg on the occasion of the Kant centenary, 1854; also Poincaré, "Hypothéses Cosmogoniques," p. 197.

[4] W. E. Wilson, *Nature*, July 9, 1903.

Having thus explained that which is in the heavens above, on the earth beneath and in the regions under the earth, what wonder if the students of the infinitely small should feel a growing confidence amounting to a conviction that in this direction lies the nearest road to the solution of all cosmical problems; that the trail is growing warm; that perhaps but a little way beyond lies the goal of every scientific man's ambition? "What," say they, "have the students of the infinitely large to offer in return that approaches in value and importance that which they have received from us? What light can the macrocosm shed upon the problems of the microcosm?"

The modern conception of the atom as a minute planetary system, with its central nucleus and encircling electrons, has been so fruitful of results in coordinating the facts of chemistry and physics that we are apt to lose sight of the fact that it is founded upon what we may not safely call more than a lucky guess, an assumption justified only by its results. A fundamental postulate of modern atomic theory is that an electron may not permanently revolve at any distance it pleases from the nucleus, but that there are certain prescribed distances called energy levels, any one of which it may occupy, while the intervening spaces are zones of instability. In them no electron may remain; through them it may pass, but as rapidly as possible, and without a stopover. For this remarkable construction no theoretical explanation has as yet been brought forward.

I think that the astronomer, waiting years for a total eclipse of the sun, or for a proper motion to be large enough to measure, must sometimes envy the student of the atomic system, and must wish that the objects of his own study would hurry up a bit. And I think, too, that the student of the atom must sometimes wish that he were dealing with something large enough to see and slow enough to follow, and that he must sometimes cast envious eyes upon the astronomer with his light years and parsecs. And confronted by this mystery of energy levels, the micro-physicist will do well to lift up his eyes and look abroad into the solar system.

Is there an analogue of energy levels in the solar system? I think we may answer in the affirmative. In saying this I have not in mind Bode's law, which prescribes the relative distances of the planets from the sun according to a modified geometric series; for, apart from the fact that no reason is evident for this series, the law breaks down at each end, with Mercury and with Neptune. There are to be found, however, two instances of energy levels with intermediate zones of instability, and, moreover, not without a suggestion of a possible cause, which has not as yet been worked out mathematically

to a satisfactory completion. These instances are found in the rings of Saturn and in the distribution of the asteroids.

The rings of Saturn are known to consist of a multitude of discrete particles, each revolving like a miniature satellite in the periodic time proper for its distance from Saturn's center. This ring system contains several divisions, or blank spaces, in which no particles are visible. Also, the inner portion of the ring system, known as the crêpe ring, is much fainter and more shadowy than the outer portion. In it the particles are evidently much more sparsely distributed.

It has been known for a long time that these divisions occur at approximately those distances at which a particle would have a time of revolution commensurable with that of one or another of Saturn's satellites, all of which lie outside the ring system. Astronomers have not been slow to endeavor to find in this fact a cause and effect relation. An elementary consideration makes it appear that a particle which bears this relation to a satellite may be expected to undergo a cumulative perturbation and be drawn eventually into an orbit of different radius, where, because it is now out of step with the disturbing influence, it must remain for a long time[5]. A closer analysis indicates that the solution is not as simple as this would make it appear.[6] The latest work on the subject, that of Goldsbrough,[7] takes into account not only the influence of the outer satellite, but also the mutual effect of all the particles in the zone in question, and arrives at the conclusion that not only can the divisions in the ring system be explained by the influence of one or the other of the satellites, but that the inner, or crêpe ring, is within the dissipative area of the fifth satellite, Rhea, and that the whole ring system lies in a feebly dissipative area due to the sixth and largest satellite, Titan. In this connection it is interesting to note that certain astronomers have believed that they have detected a progressive fading or dissipating of the crêpe ring.

This explanation of the blank spaces is to-day still fighting for recognition; it has not yet arrived. The criticisms of it[8] are directed not so much against the validity of the analysis as far as it has been carried, that is, to a first approximation, but raise (without answering) the question of the effect of second order quantities over a long period of time. Added weight is given this hypothesis,

[5] Lowell, *Observatory Bulletin* No. 66.

[6] Tisserand, "*Mécanique Céleste,*" vol. IV, p. 420.

[7] Goldsbrough: Phil. Trans. A, Vol. 222, p. 101, 1921.

[8] Greaves: Monthly Notices Roy. Ast. Soc., 82, pp. 356–359 and 360–367; 83, pp. 71–79; 1922. E. W. Brown (spring meeting, National Academy of Sciences, April, 1924) has, however, recently shown that commensurability of period necessarily carries with it instability of orbit.

however, by the fact that the same condition obtains in the system of asteroids which is found in the region between Mars and Jupiter. There are now known something like 900 of these bodies, a number large enough to allow the law of probability free play in their distribution; yet it is a fact that in those regions where the periodic time of an asteroid would be commensurable with that of Jupiter few or no asteroids are found.

In the atomic planetary system we have, of course, no exact parallel to this; for the cause of the zones of instability we must here look, not outward, but inward to the nucleus, whose structure is at present unknown. If there is something about the nucleus which produces a field of force which is slightly asymmetric or directive, and if this asymmetry rotates with a certain period, then we may expect a cumulative perturbation to be exerted upon such electrons as possess a periodic time commensurable with the nuclear period. Such a structure of the nucleus is not difficult to imagine. An elongated, or dumbbell form, with one end much more massive than the other, and the whole in rotation about its center of mass may be expected to produce such an effect. And so incomparably more intense are the accelerations in the atom than those which prevail in the more spacious and leisurely solar system that a minute cumulative effect might remove an electron from a forbidden position in a thousandth of a second, while the dissipative effect of the satellite Rhea upon the crêpe ring of Saturn may require thousands of years for completion. In this respect the contribution of astronomy to the science of the atom reminds us of the slow motion pictures which enable us to follow the flight of birds; only in this case we could wish that the pictures were not quite so slow.

We have considered certain contributions of the very small toward the solution of the problems of the very large, and vice versa; and I think we have seen that neither class of workers can afford to neglect the results of the other; that no one can hope to see his problem in its proper perspective who keeps his eyes upon it alone. Nor can we, when confronted by a cosmic problem of the first magnitude, neglect any field of scientific work in our quest for a hint toward its solution. Such a problem we shall now consider; and it is of interest to note that the only two suggestions that have as yet been advanced toward its solution represent the two extremes of scientific investigation—the very small and the very large. This problem is that which is presented to us by the second law of thermodynamics.

Shortly after the establishment of the principle of the conservation of energy in the middle of the last century, and the recognition of the fact that all the different forms of energy are mutually

convertible one into another, it was also found that such conversions did not work equally well both ways; that while mechanical work or electrical energy could be converted readily and completely into heat, the reverse transformation of heat into other forms of energy could be but partly carried out. Once energy gets into the heat form it is impossible to get it all out again. This purely empirical fact, for which no theoretical necessity has ever been shown, forms the basis of the second law of thermodynamics. A little reflection will show that the consequences of this principle present to us a problem of the first magnitude, as broad and deep as the universe.

The energy of the universe is a restless, troubled sea. Transformation and retransformation, crest and trough of the wave continually alternate; and according to the principle just stated, transformations into heat are complete, while the reverse takes place incompletely. As a consequence, the percentage of the energy of the universe which exists as heat is continually increasing, and at some time, however far in the future, all this energy will be in the form of heat, and all will have come to the same level of temperature everywhere. When this state of affairs is reached farther transformations of energy (as far as we now know) will be impossible; the universe will resemble a great pool of Bethesda, awaiting some influence from without to trouble its waters, to disturb again the level of its vast store of useless energy, and render it once more available. Clausius calls this final state "Wärmetod," (death of heat); and the relentless process of degradation which leads up to it was called by Kelvin the "dissipation of energy."

The ancient myths of our Nordic race speak of the coming of a time when both gods and men shall sink into an endless, dreamless sleep; when upon them all, both in Asgard and upon earth, shall descend the twilight, the evening, the everlasting night. This was called by the old Germans "Götterdämmerung," "The twilight of the gods," and from it is taken the inspiration for one of Wagner's operas. If we wished to express in poetic rather than in scientific language the consequences of the second law of thermodynamics, we could not better do it. Translated into the jargon of the physicist "Götterdämmerung" means "The entropy of the universe tends toward a maximum, and its available energy toward a minimum."

It appears, then, looking into the future, that the activity of the universe is steadily approaching a condition of stagnation; but what does this principle tell us of the past? Year before year, the percentage of energy existing as heat must have been less and less, until at some time, however remote, none of the energy was in this

form. And what of the year before that? Was the state of affairs constant, or did a small portion of energy exist as heat? If the latter was the case, then this must have been just before the second law of thermodynamics was placed upon the statute books. If the former, then the universe presents itself to us after the similitude of a clock, wound up, but perhaps not allowed to run for a while; but when finally released, running down, steadily and relentlessly, after its own laws; and with each hour it strikes a different scene presents itself. There was that matin hour, the fresh dawn of creation, when the morning stars sang together, and all the sons of God shouted for joy. There is now the high noon of life and activity and pleasure and pain; and there is coming that vesper hour of twilight, that "Götterdämmerung," when the restless waves of energy shall have quieted down to a dead, dark level forever.

Beautiful and poetic as this may be, there are minds to which it is not satisfactory; minds which can not regard the activity of the universe as comprised between a catastrophic beginning and an asymptotic ending, but which rather regard that portion in which we now find ourselves as but an element of the down slope of some great sine curve; minds which look beyond the approaching minimum to the beginning of a new up slope; beyond the twilight of the gods to the dawn of a new morning; which look back beyond that maximum point in the past to the older up slope which preceded it.

Perhaps we are wrong in this way of looking at the matter. Perhaps we are so accustomed to the endless rhythm and cycle that we see about us, darkness and daylight, evening and morning, summer and winter, seed time and harvest, that our whole mode of thinking may have been unconsciously molded after this pattern. Perhaps, again, we are right. The fact remains that there are scientific men who refuse to accept the second law of thermodynamics as always and everywhere true; who regard it rather as of local and temporary signification, as an expression of conditions which prevail in our immediate region of space and time; who feel that opposite conditions must have prevailed at some time in the past, and will again prevail at some time in the future; nay, more, that perhaps even now, elsewhere in the cosmos, may actually hold sway. Two suggestions of this sort have been put forward, by men whose names command serious attention—Maxwell and Arrhenius.

Maxwell's suggestion was drawn from the infinitely little—the molecular kinetics of gases.[9] Metaphysical though it may sound,

[9] "On the limitation of the second law of thermodynamics;" Appendix to Maxwell's "Theory of Heat," page 328 (1875 edition).

it is as legitimate a deduction from gas theory as is (for instance) the calculation of the mean free path of a molecule. Maxwell regards the downhill action of the second law of thermodynamics as due to the absence of a guiding intelligence, like the actions of a horse whose driver has dropped the reins. Maxwell shows how it is possible to-day for an intelligence endowed with a sight sufficiently keen and a touch sufficiently delicate to effect the handling and sorting of single molecules (and since Maxwell's day we have made a long step in this direction) to reverse the action of this law, to increase the temperature of one half of a mass of gas by withdrawing heat from the other half, to make heat run uphill, to rewind the clock, to place us on the up slope of the curve—and all without violating the principle of the conservation of energy.

In a gas at what we consider uniform temperature all the molecules have not the same velocities, their different speeds being grouped about a mean value according to a law of distribution closely resembling the well-known probability curve. This is a condition of stable equilibrium, to which every other distribution of velocities must in time revert, due to the interchange of velocities by oblique collisions at all possible angles. The whole matter hinges upon the stability of this system of non-uniform velocities. If we in any way could separate the more rapidly moving half of the molecules of a gas from the less rapidly moving half, each set of molecules would promptly redistribute its velocities about a mean, one mean value being higher than the other; and from a mass of gas at uniform temperature we would thus have produced two portions, one hotter and the other cooler than the original mass.

Maxwell imagined a gas divided into two parts, A and B, by a partition containing a great many small, massless doors, each in charge of an intelligence, or, as he quaintly called it, a "demon," with instructions to open his door whenever he saw one of the more rapidly moving molecules in A headed his way, and to keep it closed against the slower ones. Similarly, he was to allow to pass from B into A only the slower molecules. Thus the original set of molecules would, without the expenditure of any work, be sifted into two classes, the more rapid ones accumulating in B and the slower ones in A. The restorative action of collisions would again produce velocities in A nearly as fast and in B nearly as slow as those which had been lost, and the process is capable of limited repetition, ceasing to be useful when the most rapid of the slow molecules are equal to the slowest of the fast molecules.

The temperature of the hotter portion of gas may now be allowed to come to the lower level, driving a heat engine in the process, and

a certain amount of work recovered. The sorting may then be repeated, and more work recovered. All this recovered work, it is to be noted, will have come originally from a mass of gas at uniform temperature, which is cooled in the process.

The suggestion of Arrhenius for avoiding the stagnation which threatens the universe does not require the interposition of intelligence. His suggestion is drawn from the very large. Strutt's work on the radioactivity of the rocks of the earth's crust leads to the conclusion that if radioactive material were distributed in the same proportion throughout the whole mass of the earth there would be generated about 30 times as much heat as is now being lost by radiation from the earth. Two positions are open: we may assume that all the earth's radioactivity is confined to a surface layer about 40 miles deep; or we may suppose it uniformly distributed, but for some reason inactive at greater depths. Arrhenius suggests that the enormous pressures in the earth's interior inhibit radioactive transformations,[10] an idea which may at first appear strange; for we have been taught that radioactivity is something which no forces that we can bring to bear can alter.

It is true that such pressures and temperatures as can be conveniently obtained in our laboratories are powerless to alter radioactivity; but we can not exert anything like the pressure to be found in the earth's interior, nor produce a temperature that approaches within many orders that which must exist inside the sun or the stars. And it is theoretically possible that a pressure high enough might completely stop radioactive explosions of molecules.

But Arrhenius goes a step farther, and suggests that perhaps at pressures and temperatures sufficiently high, radioactive bodies may be regenerated from their decomposition products. For this purpose pressure alone would probably not be sufficient. It is one thing to force a helium atom back into the molecule whence it came, and another to provide it with the great energy it had when it was ejected. Here we need temperatures higher than we are accustomed to think about. To raise a mass of helium to such a temperature that, say, one per cent. of its atoms may possess a speed of one fifteenth that of light (an ordinary velocity of ejection) would require us to reach a temperature of over a billion degrees. The highest temperature at present ascribed to the outside of a star is perhaps 25,000 or 30,000 degrees, but the temperature at its center is classified by Jeans[11] as at least "millions." Without pressure, such temperatures might be expected to have a dissociat-

[10] Arrhenius: Das Werden der Welten, 1907; English Translation, "Worlds in the Making," 1908.

[11] Jeans, *Nature*, March 1, 1924, page 330.

ing effect; but with sufficient pressure it is conceivable that the reverse may happen.

Be this as it may, these two suggestions, drawn from the study of the large and of the small, are the only attempts that have ever been advanced toward a solution of the problem of the death of heat, and the dissipation of energy.[12] Other and better explanations may perhaps replace them; for it is difficult for many minds to conceive of our rhythmic, cyclic universe beginning abruptly and ending in stagnation. For this puzzle the key is yet to be found.

It has always been a favorite idea with me that no one is too old or too grown-up to be interested in a real, good, old-fashioned fairy story. I have demonstrated this to my own satisfaction many times; and, by your leave, I will demonstrate it to yours.

Once upon a time there was a prisoner. His crime must have been great, for he was confined in a cell without windows, where the darkness was relieved only by a faint light that came through a panel of some translucent material in a door in the eastern wall of the cell. The other three walls contained doors also, each different in form from the rest. The door of the south was hot to the touch, and warmed the cell by its radiation. The door of the west contained an always closed wicket with a shelf before it. The prisoner had learned that if (and only if) when he lay down to rest this shelf was duly swept and prepared, would he find upon it when he awoke in the morning his daily material necessities. But the door of the north was most wonderful, for about it a bluish glow played, and from it crackling sparks darted forth to meet the approach of an incautious hand.

How long the prisoner had been in this place he knew not. All his memory was of this cell. He spent much of his time in work, for in the years of his stay he had fashioned a set of rude tools from the débris that littered the floor of his cell. Day after day he would spend at his bench, making keys; for this was his hope—that he might some day make a key to fit one of the locks in the doors of his cell. He would spend weeks over a single key, only to find it useless; then he would throw it upon a pile which already contained many such discarded keys, and set to work patiently upon another.

One night, fatigued, disappointed and discouraged, he lay stretched upon the floor of his cell in slumber. And in his sleep he had a dream; for it seemed that there was in his cell an angel who took from his girdle a key of strange and yet simple form, to which

[12] Very recently (*Am. Math. Monthly*, March 1924) Lotka has put forward a third suggestion of a novel and profound nature, based upon statistical mechanics.

all the four locks yielded. And the prisoner saw in his dream that the four doors were bound together without by a great chain, reaching from door to door, and encircling the cell, so that unless all the doors were opened all must remain closed. And as the prisoner tried in his dream to see what lay beyond he awoke, to find the doors closed as he had always known them.

Then the prisoner turned to his bench and began shaping a key after the fashion of that which he had seen in the hand of the angel. He had had but a fleeting glimpse of it, and had caught but the general plan; the details had escaped him. Finally it was finished, to the best of his recollection, and with a trembling hand he tried the key in the eastern door.

The key turned, although with difficulty. At one point the prisoner had to put forth all his strength to make it pass one of the wards of the lock; yet it passed, and the bolt yielded. With a shout of joy the prisoner pushed the door outward.

It opened but the merest crack, and a blinding light filled the cell. The prisoner shut his dazzled eyes, and felt through the crack with his fingers. His dream was true; there was the chain which prevented it from opening farther. Greatly excited, he withdrew the key, and hastened to the door of the north; but here the key would turn but part way, try as he would; so back to his bench went the prisoner and worked away patiently at the key.

Days of work and trial followed before the key would turn in the north door; yet it finally turned, and the door yielded enough to show the binding chain as with the other. But in the door of the south the key would not turn at all; so back to his bench again went the prisoner and filed patiently at the key.

And lo! as he worked, through the partly opened eastern door there shone upon him a beam of the outer glory; and his heart was glad, and he sang as he shaped the key.

THE ORIGIN, NATURE AND INFLUENCE OF RELATIVITY[1]

By Professor GEORGE D. BIRKHOFF

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V. Some Relativistic Paradoxes and their Explanation

A first and insuperable paradox of the new theories is often seen in their abandonment of absolute simultaneity; it is taken to be self-evident that either two events are simultaneous or one happens before the other, and it is vigorously contended that the significance of such a statement has nothing to do with the particular method adopted for measuring time.

Very similar feelings must have been aroused when the opinion that the earth was round and not flat was first advanced, for everyday experience as well as primitive cosmogonic speculation seemed to require such flatness. In order to remove the appearance of paradox in the new hypothesis, a first step was to observe that "down" means merely "towards the earth," and need not refer to a fixed direction in space, although very nearly the same direction for long distances. Undoubtedly, a distinct mental effort was required in granting as much.

In the same way, even after the relativist points out that simultaneity obtains a genuine meaning only by reference to some system of time measurement, it is not easy to give up the belief that simultaneity is an absolute affair, and that clocks everywhere are to be adjusted so as to run in unison.

A further step was available to convince the skeptical but intelligent inquirer that the earth was spherical, namely, to inform him about the truths of geometry and the observed difference in apparent position of the sun at any two places remote from one another on the earth. Likewise, the new analysis of the concepts of space and time, and facts such as the Michelson-Morley experiment, open the way to an understanding of relativity.

The salient feature of the special theory of relativity is that all undisturbed bodies are held to be equally satisfactory for setting up systems of space-time reference. It can not be expected that the facts observed to transpire in any particular system so obtained have an absolute physical meaning; by their very nature they must be facts affected by their relation to the arbitrarily selected reference body or "particle," as we shall call it. In consequence, there

[1] Lowell lectures.

is no *a priori* basis for the identification of the facts as stated for different particles.

The apparent paradoxes of relativity are largely due to a confusion of distinct systems of space-time reference. On this account they are easily explained after suitable consideration has been given to the nature of the correlation between the various systems.

There are, of course, many results which may be stated independently of the arbitrary reference particle. For example, if light flashes back and forth along a meter stick, a perfectly definite interval of local time will elapse meanwhile on a clock attached at the end of the stick whatever its apparent velocity may be.

This is the essential physical truth embodied in the so-called hypothesis of the constancy of the velocity of light, and makes it possible to measure the natural dimensions of a body by optical signaling between its points.

On the other hand, the simultaneity of two events has only a precise meaning in relation to the particular reference particle selected. Thus, if a reference particle P is the midpoint of a meter stick, a light flash from P will reach its two ends simultaneously in P's system of space-time measurement, by the very definition of simultaneity. Now imagine a second stick which is moving relatively, the midpoint Q of which is superposed on P at the instant when the light flash starts. It is clear that (for P) the light flash will reach the approaching end of the moving stick before it reaches the receding end. In other words, the flash will not reach the ends of the moving stick simultaneously in the time system of P. But in the system of the midpoint Q of the moving stick, these two events will be simultaneous, of course.

Similarly, there is no reason to expect that the optically determined length of a meter stick in motion relative to a reference particle will be a meter which is its natural length, or that a moving clock will tick once every second in the time of a reference particle. The determination of what the facts are will depend on the selection of definite technical means for measuring the space and time of the reference particle, together with the correlation of these spaces and times in accordance with the hypothesis of relativity.

The surprising extent to which the statement of the results in the old or new theories depends on the particular technical means of measuring space and time may be brought out in a suggestive way as follows:

Suppose that a dark star enters the solar system with a velocity nearly that of light, and becomes luminous in so doing. A terrestrial observer will *see* it approach with a velocity greatly exceeding that of light. This is obvious, since if its velocity were

equal to that of light, the star would strike the earth without ever becoming visible. The apparent paradox disappears, of course, when the proper allowance is made for the time which light from the luminous star takes to reach the earth.

Henceforth it is to be understood that the space and time used are not those of events as seen at the reference particle, but with this time correction allowed for.

The relativistic correlation of the spaces and times of various reference particles is very much like that to be found in some ordinary correlation problems, which can be more readily grasped, and which will be referred to first.

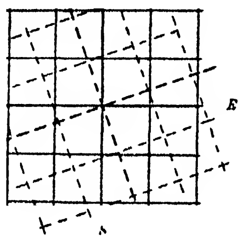

FIG. 1

Suppose that the squares of a projected city are laid out, but not exactly from north to south and from east to west because of topographical difficulties. Suppose further that it is subsequently decided to run the streets differently, say inclined at an angle of 20° to the directions first chosen. It is apparent from the figure that there will be no obvious relation between distances east and north, as measured in the two arrangements.

The easterly distance and the northerly distance between points of the city, as obtained in the two ways, are comparable to space distance and time difference between events for two reference particles in relative motion. Taking events which are simultaneous for one particle to be simultaneous for the other also, is akin to taking points on the same east and west street of the original arrangement as likewise so in the modified one. More generally, taking the distance or time between two events to be the same for both reference particles is like assuming that the distance by which one point is east or north of another will be the same whichever way it is measured.

The following problem in correlation is even more analogous to that found in relativity. Suppose that the surface of the earth is mapped on a plane by some specific method. The parallels of latitude and the meridian circles will then take definite positions (the circles and the straight lines in figure 2). Instead of the

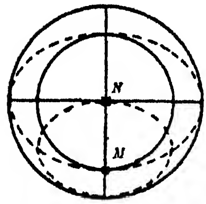

Fig. 2

north pole N, some other such pole can be selected, say the pole M. By the same method, a second map is obtained which will be quite different in appearance from the original map. If, however, the new parallels of latitude and circles of longitude are drawn on the first map, it will be possible to use them for drawing the second map. Here also is a problem in two-dimensional correlation.

There is no simple rule of correlation between the latitude and longitude of a point as measured on the two maps, and the fact serves once more to illustrate what may be expected when the various spatio-temporal systems of relativity are correlated.

A simple case of that theory is presented by particles moving on a single spatial line. A variety of particles are then directly approaching or receding from one another in empty space. To each of these there is attached a space and time found by light signaling methods. Thus, if a light flash is sent out from a reference particle A and returns by reflection at some second particle B after two seconds, then the event of the reflection is specified in space and time by the two observations at A. The space and time referred to is that of the particle A; as stated previously, the accepted technique of determination of these measurements is identical with that used in the classical theory when the reference particle A is "absolutely at rest." Since the light flash travels the same distance either way, the distance of the event signaled from A is one light-second. The time of the event will be one second after the light flash was sent out from A.

The collection of all these events is clearly two-dimensional, with one spatial dimension and one temporal dimension.

If an "observer" at A were to collect observations of events, he would naturally employ a chart in which one direction indicates distance from A, and the perpendicular direction indicates time of happening. Such a chart serves to specify events in the same way as the plane map serves to specify the points on the earth's surface. It is to be expected that the representation of events obtained is imperfect, but so is that given by a plane map of the spherical earth. In fact, the physical reality of lapse of local time

between two events at an arbitrary particle is imperfectly represented by distance in the chart, just as the physical reality of distance between two points on the surface of the earth is not represented exactly by distance on the map. For the map, the distortion is least near the poles and greatest near the equator. With the charts, a considerable distortion is found only in the case of relative velocities comparable to that of light.

Moreover, in the same way as with different choices of a pole on the earth various maps are obtained, so all the various particles yield corresponding charts. These charts will be essentially the same only for particles relatively at rest.

There is another analogy which is worthy of note. All the parts of a sphere are alike from a geometrical point of view, and yet this identity of properties is masked when the sphere is mapped upon the plane. Similarly, it is a fact that space-time is the same physically for every reference particle, and yet this is not obvious from a casual inspection of a single chart. It is desirable now to outline briefly how there can be complete relativity of this kind with respect to any reference particle, without essential paradox.

Assume that a definite particle A is selected, and that in its space and time, determined by the particular light signaling process specified above, every other particle travels with a constant velocity less than that of light, the latter velocity being unity on account of the fact that the light-second is taken as unit of distance in defining the space and time of the reference particle. This assumption means that the events at any observed particle B are represented by a straight line on A's chart.

Thus far, the only clock used is the one at A. The clock at a particle B in relative motion can be arbitrarily assumed to go at any assigned rate, and a moving measuring stick to vary in length for A according to velocity, and still no inconsistency can arise, for all the hypotheses are mutually independent.

Suppose in particular that any three Pythagorean numbers such as 3, 4, 5 (so that $3^2 + 4^2 = 5^2$) are selected. If we desire, the specific assumption about the behavior of clocks and measuring sticks may be made that, if the velocity in A's space and time is three fifths that of light, then the slowing down of clocks and the contraction of measuring sticks will be in the ratio of 4 to 5. We may extend this rule to any set of three Pythagorean numbers such as 5, 12, 13. In such a way there is obtained a purely hypothetical space-time, which is bound to be self-consistent by its very manner of definition.

At the reference particle B it is possible to imagine the same signaling process carried out, in order to obtain B's system of space-time reference. It will then be found as a result of easy

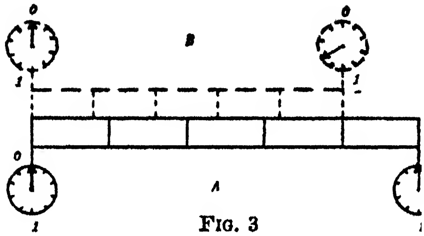

FIG. 3

algebra that the relation of A's space and time to B's space and time is exactly that of B's to A's. By the use of the same method it is also possible to find the interrelation of the space and time of a particle C to B's, by the intermediation of A's space and time. Exactly the same Pythagorean rule is found in this way to hold for B as well as for A. Hence the self-consistency of relativity follows. It may be observed that if clocks and measuring sticks do not behave as required by the Pythagorean rule, the principle of relativity does not hold.

The adjoining figure illustrates an optically determined position of a measuring stick B of one light-second in length which is moving to the right at three fifths the velocity of light relative to the reference measuring stick A whose natural length is also one light-second. It will be observed that B's optical length is only four fifths that of A. The clocks attached to the two ends of A point to the same zero of time, since a single instant of A's time is represented. The clock attached to the left-hand end of B is also taken to point to the zero of time; it will be noted that then the clock at the right-hand end of B has a lag of three fifths of a second, in agreement with the fact that events simultaneous for A will not be for B.

After one second has elapsed at A, the stick B has moved three fifths of a light-second to the right of course, and has still the optical length of four fifths. It will be seen that the same characteristic lag is found in the clocks at B, and that these have only run four fifths of a second for A.

A possible difficulty may be felt in the fact that the stick B in

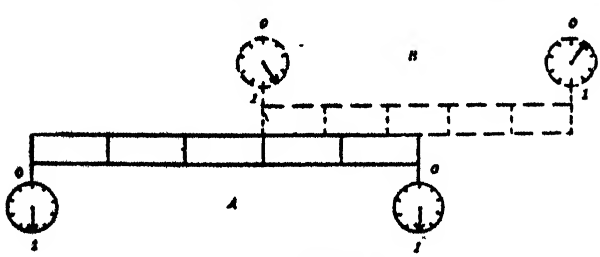

FIG. 4

motion is deemed shorter than the stick A at rest, while, if B is taken to be at rest, A is held shorter. Such a difficulty only arises from the attempt to overlook the difference between the reference systems attached to A and B, and treat them as identical. A glance back at the two sets of streets of the hypothetical city (Figure 1) shows that the easterly distance between a pair of north and south streets of the second arrangement, measured in the first, exceeds that between a pair of north and south streets of the first arrangement, and that, notwithstanding, the same is true when the rôle of the two arrangements is interchanged. This analogy indicates the lack of ground for the stated difficulty, or for any similar difficulty in the behavior of clocks in relative motion.

After these preliminaries we are fully prepared to deal with some amusing and instructive relativistic paradoxes, the explanation of which illustrates various results of the theory.

The Quest of the Absolute

Despite the *dictum* of relativity, may it not be possible to define absolute space and time? The method to be proposed can be best understood after its analogue in Newton's theory for determining an "absolute space" has been formulated.

According to the Newtonian laws, the center of gravity, C, of the sidereal universe moves with uniform velocity in a straight line. The "absolute" space may be taken to be that attached to a hypothetical particle at C. In other words, the absolute space is the particular one for which the center of gravity is at rest. It is for this space only that the motion of matter everywhere is most symmetrically distributed in direction, and that the total energy of motion is least.

In the special theory of relativity it is possible to proceed by a somewhat more involved but entirely similar method, to define an absolute space and time. It is simplest to do this when there is a set of mass particles in uniform rectilinear motion. Then there can be found a hypothetical reference particle C, for which the attached space and time have a peculiar property, namely, that there is no "apparent momentum" in any direction. It is again a system of reference for which the motion is symmetrically distributed in all directions. When there are only two particles of equal mass, C will lie half way between them at rest in the absolute space. If the mass particles are interacting, it is still possible to obtain a hypothetical particle C, such that for any event E at C, some particle D at the event has the symmetrical distribution of motion sought. Here we may define the absolute space as that of D at E, and absolute time as given by the clock moving with C. The main

fact to observe is that, despite the increasing complexity of definition, the space and time called absolute can be chosen by a symmetrical method. Even in the general theory of relativity it is possible to proceed similarly, since it is known that the space of a particle at an event can be uniquely defined.

The fundamental objection to any definition of this sort is that the most convenient statement of physical law is accomplished without any use of such an absolute system of reference. It is true that the absolute space and time specifically proposed present a further difficulty, namely, that large quantities of matter, so extremely remote from the sidereal universe as not to be observable, might greatly modify the space and time called absolute, which seems unreasonable. But mere intellectual convenience is the major consideration requiring the abandonment of an artificial absolute space and time.

The essential meaning of relativity is thus that the laws of nature are most easily stated in terms of systems of space-time reference not uniquely defined.

The Clock Paradox

The following paradox is often baffling. Two clocks K and L are at a particle P. If the second clock is moved in any manner away from P and then back again, it will be found to have gone more slowly than the first clock, although the rates will still be the same at the two comparisons. However, the situation seems entirely reciprocal. In the same process, the first clock leaves the second and is then brought into coincidence with it again. It appears as if not only L registers less time elapsed than K, but also K registers less time than L. Now such a state of affairs is obviously impossible.

The answer to the paradox is that only K remains in undisturbed motion at P. By the stated rule, it is clear that L will go more slowly than K, so that less time will elapse at L. Since the motion of L is disturbed, it can not be taken to coincide with a reference particle during the process. If L were not disturbed it would necessarily remain in coincidence with P. Thus the reason for the apparent paradox lies in a deceptive appearance of symmetry between the two clocks.

The Age of Light

Astronomers tell us that light arriving from a very distant star is extraordinarily old. But, according to the theories of relativity, light is ageless. In fact, imagine a clock traveling as fast as light. The Pythagorean rule shows that the corresponding Pythagorean

triplet is 1, 0, 1. Hence, contraction of measuring sticks to *nil* and a complete stopping of clocks takes place in motion with the velocity of light. Since the clock at the light wave is not going, the wave can not age at all. More precisely, we may imagine that the clock travels at a rate slightly less than that of light; then, in the reference system attached to this clock the aging of the light will be very small while the light leaves the distant star and travels to the earth. Of course the apparent distance from star to earth will be greatly reduced for such a reference system, as obtained by the optical method. The conclusion follows that the age of a light wave is entirely relative to the particular space and time of reference selected.

For the astronomer the reference space and time selected is that attached to the sun and the fixed stars. It is in this sense that the usual astronomical statement has meaning.

An Adventure in Time and Space

The episode which we now propose to tell is one which seems at first to transcend the imagination, and yet which is entirely in order for the relativist.

A youth, bidding farewell to his companions, enters a properly constructed projectile and is hurled away from the earth with a velocity nearly that of light. (As a matter of fact it would require at least a month of constant high acceleration to acquire safely such an extraordinary velocity.) The projectile is directed toward an enormous star thirty light-years distant. On approaching the star, its gravitational attraction is used to reverse the direction of the projectile, and he returns safely to the earth. For him the entire journey will take a very short time and he will still be young. Yet his companions will have become old men.

This paradox is explained just as the preceding one was. Relative to the earth, his clock will tick off the seconds very slowly, and his physiological activities will go on at a proportionately slow rate. If we undertake to specify what happens relative to the daring youth, we are no longer on familiar ground, since the projectile is not in undisturbed motion during its entire flight.

It is interesting to inquire what would be "seen" to transpire through suitable telescopes. From the earth events would appear to happen very slowly at the projectile on its sixty year outward journey at apparently only half the velocity of light. Then the projectile would be seen to shoot back with an incredible velocity greatly exceeding that of light, and would reach the earth in a very short time during which events in the projectile are observed to happen very rapidly. The youth would undergo a still more

curious experience. In particular he would see the apparent distance between the earth and star become very small, while their apparent diameters would be unaffected.

The Speed Paradox

It has been stated that the velocity of a particle can not exceed that of light in relativistic space-time. But why can we not proceed as follows? Consider a first particle P, moving in one direction with two thirds the velocity of light relative to Q, and another particle R, moving in the opposite direction with the same velocity relative to Q. Then it would seem that the velocity of R relative to P is four thirds that of light.

It is clear that this conclusion involves the assumption that the velocity of P relative to Q and the velocity of R relative to Q will combine to give the velocity of R relative to P. But what is really obtained by this addition is the velocity of R relative to P *in the Q system of reference*, and not in the P system as desired. Thus, this paradox, too, is explained by the confusion of reference systems. As a matter of fact, the velocity of R relative to P will be only twelve thirteenths of that of light. The same process may be indefinitely continued for any number of particles, each of whose velocities relative to its predecessor is two thirds that of light; and yet the velocity of the last particle relative to the first will still be less than that of light. The mathematical formulas justify this remarkable conclusion.

Is Mass Constant?

In classical physics mass is a constant. If a force, say equal to only one pound, is constantly exerted on a pound of matter in empty space, its velocity will exceed that of light by the end of a year. But this can not happen in the theory of relativity, since no velocity can exceed that of light. The only possible conclusion seems to be that the mass increases as the velocity does. Hence mass seems to be at once constant and variable.

To explain the paradox, let us suppose the force to have acted for only one second. The mass will possess a certain velocity (about 32 feet per second) relative to the initial reference system. Adopt now the reference system for which the mass is at rest at the instant. Since the conditions are exactly as they were at first, the velocity will be increased relatively by the same amount as before during the next second, and this will continue indefinitely.

But, as we observed in the discussion of the preceding paradox, it is not possible to make the velocity equal that of light by such a process. Consequently, the velocity will increase indefinitely, but never can become as great as that of light.

Hence in the first reference system it will appear as though the mass were responding less and less readily to the action of the force. The "apparent" mass may then be said to increase, although the "natural" mass of one pound remains unaltered.

The fact that increase of apparent mass occurs with increase of apparent velocity is often stated in the more specific but not quite exact form that increase in apparent mass is equal to the increase in kinetic energy.

Is Space Curved?

It has been pointed out that in the special theory of relativity, empty space is flat or Euclidean. It is often said that in the general theory, space is curved because of the presence of matter. What is the meaning of this statement?

A curved space is one in which experiments in spatial measurement are not in accord with ordinary geometry. For example, on the surface of the sphere, distances and angles obey different laws than in the plane. Hence the sphere is curved.

By the general theory of relativity, there is not usually to be found the stationary condition essential for comparative spatial measurement. However, the solar space attached to the sun happens to be nearly stationary, since the planets only disturb the sun slightly. It turns out that the solar space so obtained is curved, so that, for instance, the ratio of the distance around a circle with its center at the sun to its distance through is not exactly the ratio of ordinary geometry.

Of course distance may be defined anew so that the space about the sun is Euclidean, in the same way as distance on the sphere may be defined as distance on a plane map of the sphere. But such distance will not then be that determined by the use of the measuring stick in space, and lacks physical significance.

Is Space Finite?

It follows in Einstein's general theory that if the density of matter does not diminish indefinitely at great distances, then the spatial universe is finite in extent. This seems very paradoxical at first. However, if we imagine a thoroughly two-dimensional being, somehow confined to move in the surface of a very large sphere (to him like a plane), then his spatial experience will be two-dimensional just as our own experience is three-dimensional. Moreover, to him space will appear not only unbounded, but infinite, whereas in fact it is unbounded and finite. This familiar illustration is sufficient to make it conceivable how space may be unbounded, and yet finite in extent.

At present the astronomical evidence does not point to the finiteness of space.

This completes the selected list of paradoxes. It has appeared that nearly all these apparent paradoxes have arisen because of a confusion of different systems of space-time reference. Yet it is possible and convenient to hold fast to a single arbitrary system of reference, provided only the arbitrariness be recognized. In the same way, position on the earth is defined once for all in terms of latitude and longitude, which involves the arbitrary initial choice of a pole of reference. Despite the fact that an arbitrary method of earth measurement is selected, no one feels obliged to consider the interrelation of two systems of reference obtained by selecting two poles. Of course the alikeness of the sphere in all its parts and in every direction, and the fundamental importance of the concept of distance, are admitted, and the distortion of distances on the map because of the selection of a particular pole is expected.

Similarly, in dealing with a particular physical problem, it is desirable to adhere to a definite means of space-time measurement, while the alikeness of space-time throughout, as embodied in the principle of relativity, and also the fundamental nature of the interval of local time between events, are recognized. Peculiarities observed in the behavior of clocks, measuring sticks, etc., are accepted as only natural, for it is understood that these phenomena represent a kind of apparent distortion relative to the selected reference body. In this way it is easy to arrive at a satisfactory mental attitude toward the new doctrines.

THE MISSISSIPPI GULF IN THE MIDDLE AND UPPER EOCENE

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In previous numbers of this journal I have given accounts of the Mississippi embayment during the Upper Cretaceous and Lower Eocene.[1] The approaching publication of a long delayed monograph on the middle and upper Eocene floras of southeastern North America[2] seems an appropriate time for giving a popular account of some of the outstanding items in the history of this interesting region during those times.

There is a perennial fascination in all history, and this is especially true of the history of the earth—eons old and ever young. Like the humble peasants passing their lives over the buried sites of some powerful city of antiquity, most of us are inclined to think of the present as having come down to us unchanged out of the distant past.

As the Bedouin may roam over the sites of Nineveh or Babylon and know them not, or the rude fisherman of Joppa know not of Tyre, or the peasant Turk have ever learned of Troy or Sardis, so we may pass our lives on the site of countless dramas of the past without ever a realization of the wonders buried in the ground beneath our feet, and this is more true of geology than of archeology, for everywhere that man lives he lives on the surface of a buried earth history.

The region of the lower Mississippi Valley and the states bordering the present Gulf of Mexico is one that is physiographically unique; it rivals the Paris Basin in the unity of its geologic history, in its stability in altitude, and in the abundance of its alternating marine faunas and terrestrial floras. Because of its large size, its proximity to the American Tropics, and its long, uniform and relatively unbroken geologic record, its fossil plants also furnish unique and invaluable suggestions as to the evolution and geographic distribution of floras. During the whole of the Tertiary period it was the low-lying southern part of a continental land mass that was bordered on the south and southeast by an ocean, so that its meteorologic conditions were comparatively uniform. Throughout its long

[1] Berry, Edward W., SCIENTIFIC MONTHLY, Vol. 4, 1917, pp. 274–283, 8 figs.; Vol. 9, pp. 131–144, 6 figs., 1919.

[2] Berry, Edward W., U. S. Geol. Survey Prof. Paper 92 (in press).

history tectonic activity was so slight as to be negligible; no mountain ranges were formed, and the strata deposited were almost undisturbed. Whether the alternating inundations and emergences of these low-lying coastal lands were due to changes in the level of the land or to changes in the level of the sea, these changes were relatively slight as compared with those that occurred, for example, in the western United States or in southern Europe, two regions whose paleobotanic history has been fairly well worked out. The record of the evolution of the successive floras in southeastern North America was, therefore, not complicated by such a diversity of conditions, as it was in the uplifting Rocky Mountains or in the mountainous areas of central and southern Europe, and it is consequently more easily deciphered and more readily applied to the interpretation of geologic history.

With the drawing to a close of lower Eocene times in southeastern North America, an event that happened several millions of years ago, most or all of the area of our tier of Gulf states gradually became emerged from the waters of the lower Eocene sea that had covered them. The process was a slow one, the land became fully inhabited and densely forested. Had we been present we would not have known that these momentous changes were in progress. These long intervals of emergence are the lost chapters of earth history. Nature's sedimentary records of such times are largely stored beyond the reach of humanity, and we can only infer their duration from the observed changes in life when once again we can pick up the record that remains in those parts of the earth's crust where this record can be observed.

The middle Eocene in this region is called the Claiborne from a small settlement of that name on Alabama River, where Eocene deposits were in 1833 for the first time recognized in North America. Claiborne time is inaugurated for us with the sediments laid down by a readvance of the waters of the Mississippi Gulf or the middle Eocene Gulf of Mexico over this region. These were deposited on the worn surface of sands and clays of the lower Eocene, and, as we find them to-day in Alabama and Mississippi, consist of aluminous sandstones and siliceous claystones, in general sparingly fossiliferous, but in places glauconitic or calcareous and with fossils. This is the Tallahatta buhrstone of the geologists, so named from the old English name for such a cellular hard rock adapted for use as mill stones. West of the Mississippi River these initial Claiborne deposits are reddish sands more or less gypsiferous, colored and consolidated by iron oxide, which may be an altered greensand, and containing beds of clay and lignite. This is the Mount Selman formation of the Texas geologists.

With the advance of the sea inland the character of the sediments changes somewhat and becomes calcareous clayey sands or sandy clays, usually containing large numbers of mostly marine fossils. These are termed the Lisbon formation from the landing of that name on Alabama River. Still higher in the section is a thin deposit of no great extent of highly fossiliferous greensand which geologists call the Gosport formation, taking the name from another nearby river landing. The Gosport forms the uppermost division of the Claiborne group and in its topmost layers at Claiborne landing it contains a lens of estuary clay packed with the remains of the foliage of the trees that grew in the vicinity at the close of Claiborne time when the Claiborne sea was withdrawing to the southward.

This Alabama succession of Tallahatta, Lisbon and Gosport formations is usually considered as the typical one for the middle Eocene of North America. As might be expected, when these formations are traced for long distances they lose their identity. West of the Mississippi River in Louisiana but two formations have been recognized. These are an older known as the St. Maurice and an upper one known as the Yegua—the latter containing many old swamp deposits and fossil plants, and indicating that at the time the Lisbon and Gosport formations were being deposited in the sea in the area east of the present Mississippi River, the region of northwestern Mississippi, southeastern Arkansas, northern Louisiana and adjacent areas in Texas was a low land surface with a luxuriant vegetation and many swamps.

What might be called the standard Texas section consists of the Mount Selman formation, already mentioned, overlain by a series of yellow sands and clays with lenses of calcareous fossiliferous greensand, known as the Cook Mountain formation, which in turn was overlain by the Yegua formation already mentioned, and which continued to accumulate on the coastal lands of Texas while the lower Jackson sea advanced up the Mississippi Valley almost to the mouth of the Ohio, spread northward over eastern North Carolina, and inland over the whole Coastal Plain of Georgia. Except across Texas, where the Jackson deposits were largely sands and clays laid down along the shores, with occasional slight incursions of the sea bringing in a few marine forms, such as oyster beds, the sediments of Jackson time are prevailingly calcareous and often rather pure limestones. This is especially true in Mississippi, Alabama, Georgia and Florida. Toward the head of the Mississippi Gulf in northeastern Arkansas and western Tennessee where the marine waters were shallowest and where river-borne sediments were dominant, sands and muds eventually smothered the oyster beds and,

after lower Jackson time, the sediments were laid down in swamps or by streams on the land.

The layman is not especially interested in the unfamiliar swarming life of these middle and upper Eocene seas. Of the hundreds of fossil shells that to-day represent this life of long ago about the only familiar forms are the oyster, scallop and cockle. There were many corals, especially during the Jackson, and many representatives of warmer water conditions than obtain to-day in corresponding latitudes. Jackson time introduces other and strange elements into the life of these long-vanished seas. The most striking of these was the ancestral toothed whales or Zeuglodons, which must have been present in great numbers, for we find their teeth and bones all the way from North Carolina and Florida to Louisiana and Arkansas along the line of this ancient sea coast.

These primitive whales appear to have originated from semiamphibious land mammals in the early Eocene in northern Africa at a time when seas similar to the Mississippi gulf covered the Libyan desert. From thence they spread rapidly to Europe and North America and even to southern South America and Australia. The Zeuglodons of the ancient Gulf of Mexico were quite unlike modern whales, being 50–70 feet long, more than half of which was tail, and at their largest girth not more than 6–8 feet in diameter. The head was relatively small with a tapering snout provided with numerous conical grasping teeth and back of these large cutting teeth with two roots, giving them a yoke-like appearance which is the origin of the term Zeuglodon. Their fore limbs were paddles and their hind limbs had already become vestigial and did not protrude through the skin. They were evidently good swimmers and divers, and their bones were widely scattered over the soft bottoms of the Jackson sea.

Associated with these Zeuglodon bones of several species are the teeth of several species of sharks, and the bones of a marine snake. Except for a fresh water turtle no remains of the animals of the land have been found in the Jackson and this is a great misfortune, for a marvelous mammalian fauna has been found in the basin deposits of this age known as the Bridger and Uinta in Wyoming and Utah. This embraces horses, tapirs, rhinoceroses, camels, titanotheres, along with their attendant carnivores, giant pigs and insectivores, and some at least of these types must have inhabited the well-wooded country that bordered the Jackson sea, but their bones have hitherto evaded the collector.

Our vistas of these shores and the earlier border lands of Claiborne time are hence restricted to landscapes alive with vegetation of strange and interesting types but with animals other than in-

sects unknown.[3] It would be interesting to picture amphibious rhinoceroses and giant pigs in the shallow bayous, and tapirs in the swamps, but we can not be sure of their existence here until their bones are actually found.

The shores were low and for the most part heavily wooded, and the climate was warm and humid, warmer than in lower Eocene times, and plenty warm enough for crocodiles none of which, however, have been discovered in the Claiborne or Jackson deposits, although they were present in this region during the lower Eocene.

The middle Eocene or Claiborne flora that lined the Mississippi Gulf represents but few survivors from the lower Eocene—only 9 or 10 out of over 400 species. Some of the Claiborne plants were the modified descendants of lower Eocene native species, but a good many appear to represent immigrants from Equatorial America which spread northward with the warming of the climate. These came by land, over the waves by means of drift seeds propelled by ocean currents, or in the stomachs of birds.

A remarkable drift seed is that of a form of Carapa, a member of the mangrove association, the seeds of which are a familiar element in the Oriental sea drift. Another striking element of both the Claiborne and Jackson floras was a large species of gregarious fern belonging to the genus Acrostichum, whose modern representative flourishes in tidal swamps in the Tropics. Four other ferns are known from the Claiborne as well as cannas and 6 different palms. There were figs and sea grapes, many leguminous plants, soapberries, alligator pears, ironwoods, cinnamons, gums and persimmons. One of the most interesting Claiborne fossils is the large seeds of a plant closely related to the existing Sapote of tropical America, growing in those far-off days in northern Mississippi.

Another interesting Claiborne plant is the one shown in the accompanying illustration and belonging to the genus Copaifera. It is represented in the Yegua formation by the compressed, large single-seeded pods (Fig. 1). The modern forms number about 16 species of trees—four in tropical Africa and the balance in America, where they range from the Antilles to the Amazon basin. They yield the commercial gum or balsam known as Copaiba gum and have unarmed branches and even-pinnate leaves of a few small leaflets. This Claiborne form is the only one known from North America. Another very common Claiborne plant belonging to the same tribe as the orange, lemon and grapefruit is that shown in Fig. 2 and referred to an extinct genus known as Citrophyllum. It had large well-marked leaves with conspicuously winged leafstalks like a modern lemon.

[3] Dragon flies and ants have been found in the Jackson.

FIG. 1. THE CLAIBORNE COPAIBA GUM
Copaifera yeguana Berry, natural size, based on the existing *Copaifera langsdorfii* Desf., of Brazil.

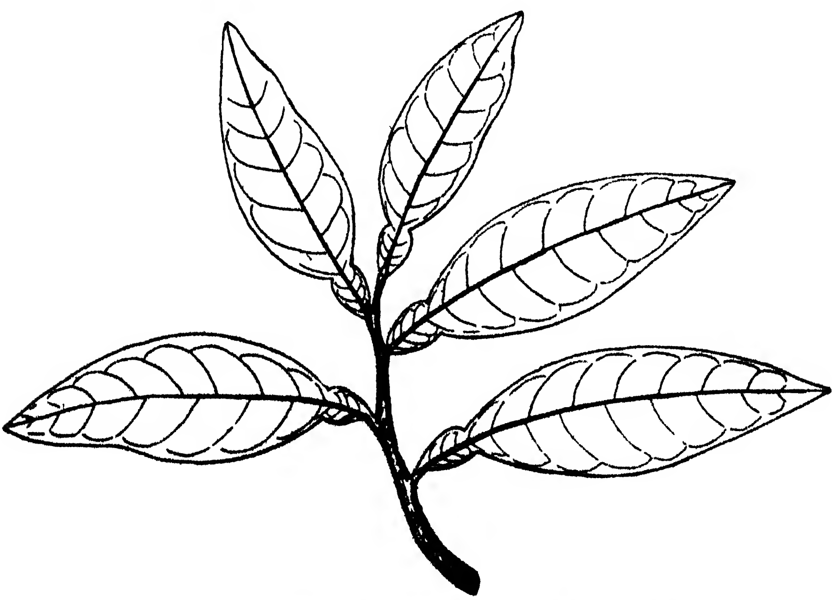

FIG. 2. THE CLAIBORNE REPRESENTATIVE OF THE ORANGE TRIBE
Citrophyllum eocenicum Berry, 4/7 natural size.

The upper Eocene or Jackson is much richer in fossil plants than the middle Eocene. One of the most interesting localities is in the lower Jackson, where the sea spread far inland over Georgia. At this place, some few miles west of Augusta, there was a shallow tidal estuary lined with mangrove swamps forming an upper Eocene picture like that to be seen to-day around the shores of Miami, Florida, which latter locality marks the northern limit of

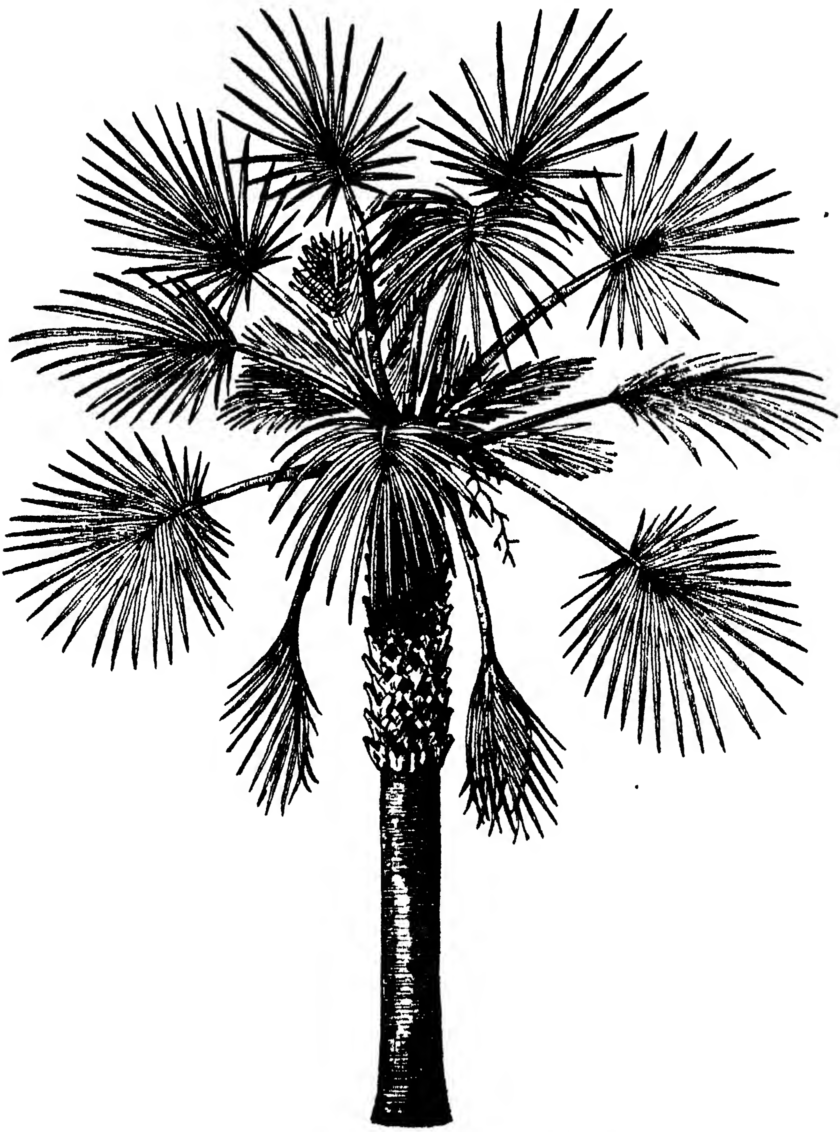

FIG. 3. THE JACKSON SABAL-LIKE PALM
Sabalites vicksburgensis Berry, about 1/50 natural size.

the modern mangrove. These curious plants with their prop-like stilt roots live in dense array on tidal mudbanks and have developed a curious resistance to salt water, flourishing in such situations as

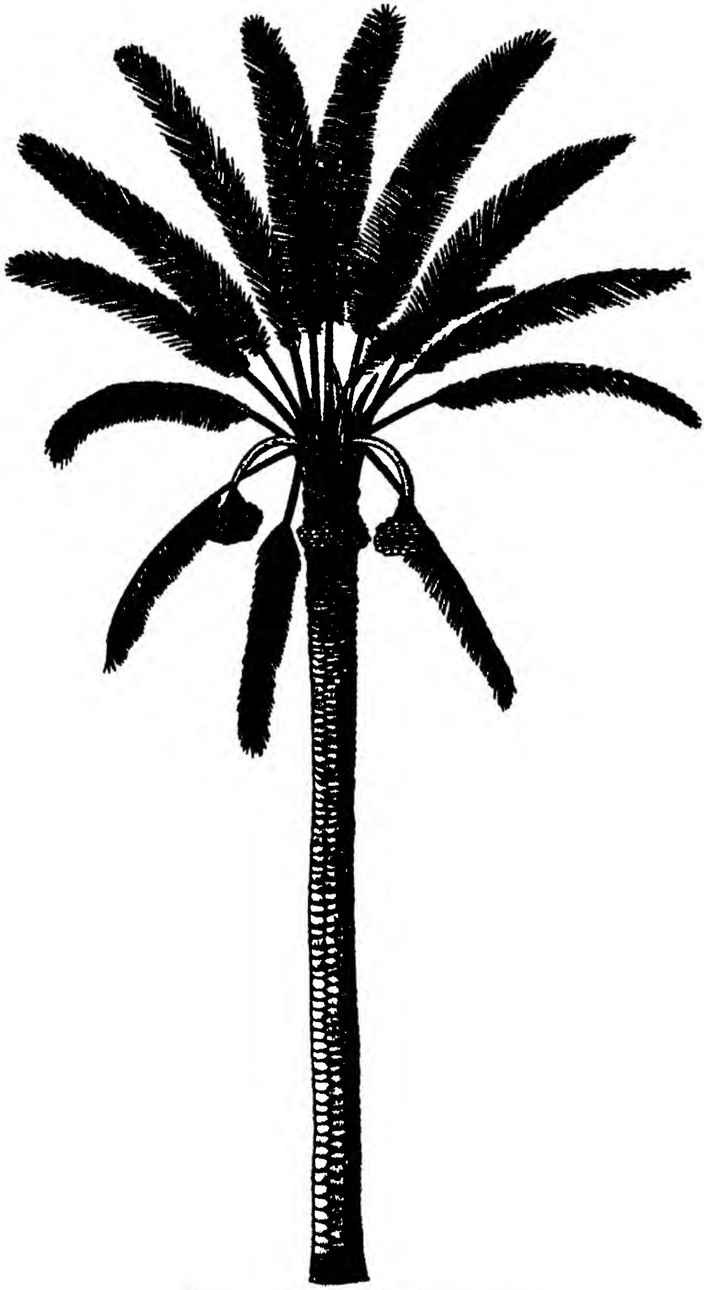

FIG. 4. THE JACKSON DATE PALM
Phoenicites occidentalis Berry, about 1/80 natural size.

Panama Bay, where the tremendous tides almost submerge them twice a day. The fruits sprout on the trees and when they have reached a considerable size drop into the water and are carried about by ocean currents until they strike root in shallow water and start a new colony. They are great land builders and are found in the estuaries of all tropical coasts.

Both fan and feather palms were a familiar element along the Jackson coasts where they are now represented by the petrified stems and fruits as well as the leaves, representing eight different species. One of the most common of these is a beautiful species of Thrinax much like the existing Thatch palms of the Antilles. Another and larger fan palm was much like our modern cabbage palmetto, and a restoration of this Jackson species of Sabalites, as it is called, is shown in the accompanying illustration (Fig. 3).

Perhaps the most spectacular of the palms is represented by leaf fragments and fruits found in Texas which show it to have been closely related to the modern date palm. This striking Jackson plant is shown as restored in Fig. 4. All the modern date palms are confined to the Old World and this Jackson species is the only member of the genus known from the Western Hemisphere. The peculiar seeds which have been found fossil remove any uncertainty as to its relationship. It is the finding of such things as date palms, nutmegs and nipa palms, all of which occur in the Jackson, thousands of miles from their existing haunts, that is one of the never-ending joys of paleontological study.

There are six figs, two sea grapes, a custard apple, 12 leguminous trees, 16 different lauraceous trees, ironwoods, dillys, gums and many other things that would be entire strangers in the existing floras of our Gulf Coast that flourished in that region during Jackson time.

One of these is the so-called tropical cedar (Cedrela) a restored leaf of which is shown in Fig. 5. Cedrela is a genus of trees with about 10 existing species in tropical America, where they are mostly confined to the mainland, although during the Tertiary they extended over the Antilles to the southern United States. They are found in the lower as well as the upper Eocene around the Mississippi Gulf, and represent immigrants from Equatorial America which have since become extinct in the United States as a result of the cooling climate during Miocene times.

Finally, there is presented in the form of the restoration shown in Figure 6 a large fruited persimmon found in the Jackson deposits of Texas, where it is represented by leaves and the enlarged and persistent calyx that subtends the fleshy fruits. The soft fruits soon decay and the contained seeds have not been detected in the

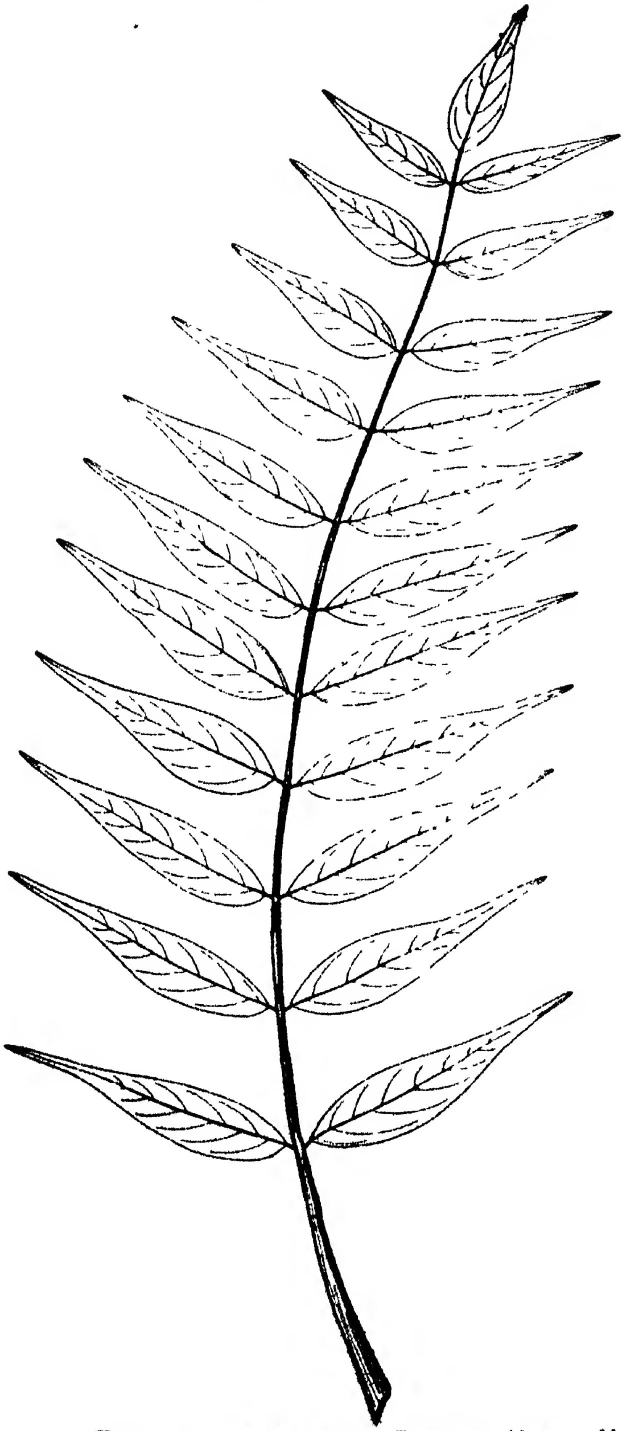

FIG. 5. A LEAF OF THE JACKSON "CEDAR"
Cedrela jacksoniana Berry, about 3/7 natural size.

rocks, but the calyx, indicating a fruit nearly as large as the present day cultivated Japanese persimmons, escaped destruction in this as well as in many other cases, and was preserved as an unmistakable token of the long vanished soft fruits of this Jackson species.

Every one in our middle and south Atlantic states is familiar with our common persimmon and its astringent fruits looking like decayed plums and inseparably associated in the folklore of the South with "possums." Few, however, know that the persimmon belongs to the ebony family and that the latter has nearly 300 existing species almost all of which are confined to the tropical countries of the world, being found on all the continents.

Persimmons are first found at the dawn of the middle Cretaceous and they have a long and interesting geological history—their leaves, petrified fruits, seeds and especially their leathery persistent calices being of frequent occurrence in the Upper Cretaceous and Tertiary rocks of the Northern Hemisphere. We can but marvel at the slight structural changes they exhibit in the vast stretches of time that they have been in existence, in fact one of the outstanding results of paleontological discovery has been the immense antiquity of most organic types, even including man.

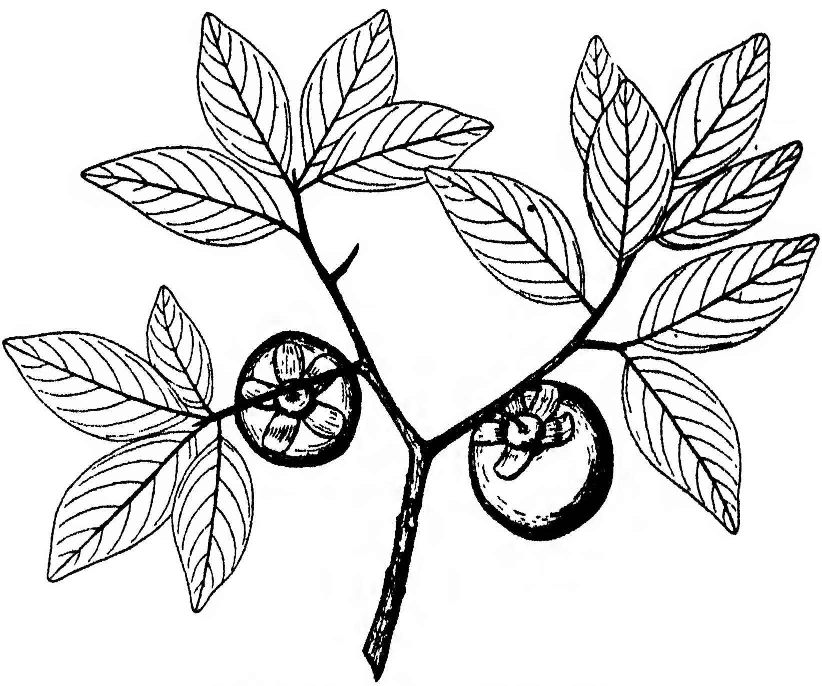

FIG. 6. A RESTORATION OF THE JACKSON PERSIMMON *Diospyros miriflorianа* Berry, about 3/7 natural size.

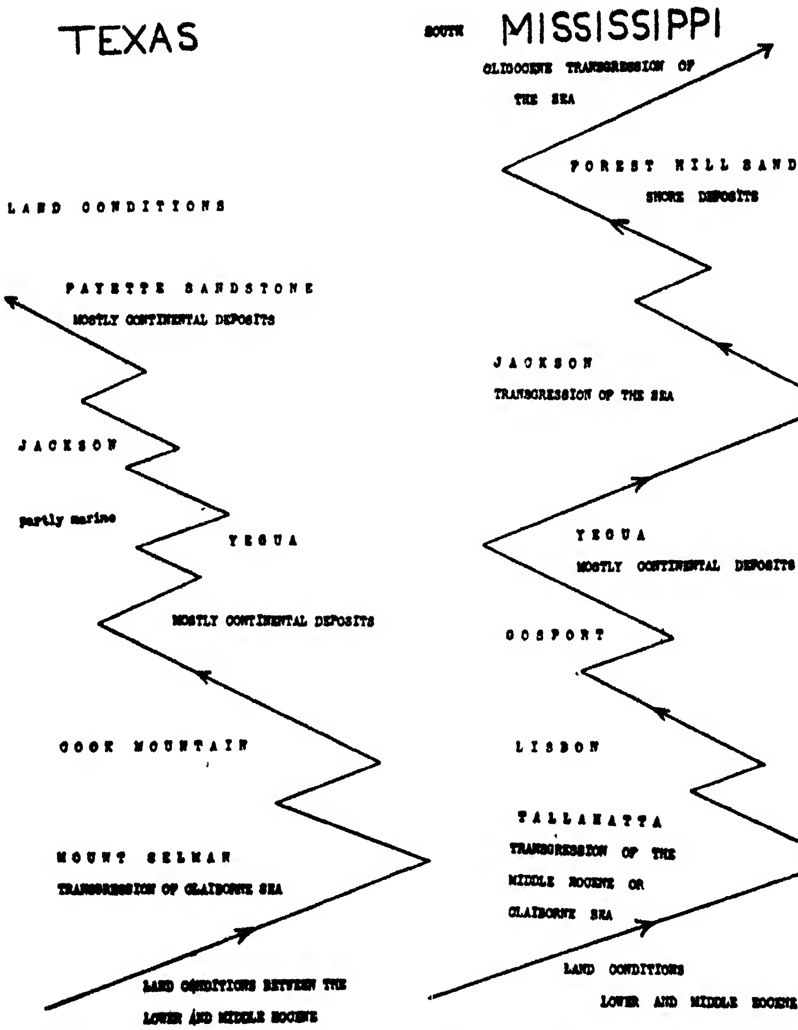

FIG. 7. MOVEMENTS OF THE STRAND LINE IN WESTERN AND EASTERN GULF AREAS DURING THE MIDDLE AND UPPER EOCENE.

Toward the close of Eocene time the shrinking of the waters of the Mississippi Gulf, already pronounced in the region west of the Mississippi River, became apparent along the eastern shores of the gulf. There is some question whether or not there was any large area that became emerged from the sea at this time, but there was certainly enough of a recession toward the southward of marine conditions to permit the deposition of a series of beach sands, interspersed with swamp deposits, now represented by lignite seams.

Deposits of this sort can be traced for a considerable distance in the state of Mississippi, where they are called the Forest Hill sands,

and where they contain fossil plants that show them to be, partly at least, of Jackson age.

This shallowing and complete withdrawal of the sea from the Texas region, and partial withdrawal east of the Mississippi River, marks the boundary for geologists between the Eocene and Oligocene, the latter epoch being inaugurated from Mississippi on the west to Florida and Georgia on the east by a renewal of typical marine conditions and the deposition of the extensive impure limestones known as the Vicksburg limestone, which extends westward a short distance beyond the river in the state of Louisiana.

I have attempted to give a graphic summary of the middle and upper Eocene history of the Mississippi Gulf in Figure 7, in which the oblique lines represent the forward and backward movement during those times of the coast or strand line. The lapse of time is represented by the interval from the bottom to the top of the diagram. Thus the reader is, in effect, looking at an idealized cross section of the deposits laid down during the middle and upper Eocene in this region, those to the left of the strand line, that is, to the south of it, representing sediments deposited in the sea; and those to the right of the strand line, that is, to the north of it, representing sediments deposited on the land by rivers and lakes, in deltas, by the wind, or the accumulation of organic débris in swamps.

SKIDDING ON THE ROAD TO SCIENCE

By F. W. HODGE

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Every student of science has doubtless been confronted at times with testimony so indisputable as to give more than reasonable support in formulating a working hypothesis; but I know of no instance pointing to the extreme care that should be exercised in developing a scientific theory than one which recently came within the experience of a fellow-student and myself respecting a subject of Southwestern archeology and ethnology. The story runs in this fashion:

In 1893 an Indian agent for the Pueblo Indians of New Mexico visited Zuñi, where he was given several small terracotta heads typical of thousands that have been unearthed at San Juan Teotihuacan, Mexico, about 1,500 miles away. The heads were said to have been taken from the middle of a large block of adobe that had served as the cornerstone of the old Franciscan church at Zuñi, built about 1692, but which had been broken open during the process of repairing the edifice. The agent frankly admitted that he was not present when the heads were found, but that to the best of his recollection they were given to him by a Presbyterian missionary, resident among the Zuñi Indians at that time. In sending the specimens as a gift to my friend and confrère in 1914, the agent wrote that the large adobe block had been made hollow and the objects placed therein in a rough box or receptacle which had practically disappeared through decay. In addition to the heads there were other Indian objects, such as arrowheads and small, rude stone hatchets. The missionary, according to the story, kept some of the heads and brought the others to the agent in the belief that he might be able to give her some information as to their origin. The agent also expressed the belief that the heads would never have been brought to light had it not been that the block of adobe in which they were found was so large that it was broken to pieces in order that it might be hauled away.

So much for the agent's account, which bears the stamp of verisimilitude except in a couple of minor particulars, namely: It is hardly likely that any one would ask an Indian agent for information respecting things Indian; and we are left to surmise why a few pagan articles were found in the wall of a church, to the neglect of those sacred accompaniments that one would expect to

find in the cornerstone of a Christian edifice. Yet it does not require a great stretch of imagination to assume that the Franciscans exercised that liberal spirit toward the Indians which won their friendship and their aid, especially in the erection of their churches and monasteries; therefore, it seemed not beyond the bounds of reason to believe that the early Spanish missionaries were prompted to offer concessions to the natives, even to the extent suggested; whereas the absence of Christian articles might be accounted for either by decay or because the Indian agent, not having been present, was not informed of them.

In any event, this fly in the ointment will perhaps seem to the layman of minor importance by comparison with the occurrence, at all, of Mexican objects in a New Mexican pueblo so far from their place of origin. Yet, Indian artifacts traveled vast distances. Catlinite found its way through channels of trade from the present Pipestone County, Minnesota, to tribes living hundreds of miles away; obsidian from the Rocky Mountain region has been discovered in Ohio mounds; turquois, evidently from New Mexico, has been found in Mississippi diggings; objects of copper from the region of the Great Lakes have been unearthed from sites of Indian settlements in the southeastern states, and Pacific coast shells occasion no surprise when recovered in the course of excavation of ancient Pueblo villages in the arid region of our southwest, hundreds of miles from the source of supply; while conchs from the Gulf of Mexico are often encountered among archeological remains far inland, not to mention dentalium-shells which found their way from Pacific shores to the Arikara of North Dakota, who also received plant products by trade from southern Arizona and New Mexico.

But we have more direct evidence of contact between Zuñi and Indians of the Valley of Mexico, which might not unreasonably have accounted for the presence of Mexican artifacts so far from home as the cornerstone of a Zuñi church.

If we go back to the year 1542, we will find that when Francisco Vasquez Coronado reached the Zuñi pueblos with his army on the return journey to Mexico, he "rested before starting across the wilderness, because this was the last of the settlements in that country. The whole country was left well disposed and at peace, *and several of our Indian allies remained there.*" Forty-one years later, Antonio de Espejo reached Zuñi from the Rio Grande, where he found crosses erected, "and here we found three Christian Indians, who said their names were Andrés of Cuyuacan, Gaspar of Mexico, and Anton of Guadalajara, and stated that they had come with the said Governor Francisco Vasquez [Coronado]. We

instructed them again in the Mexican tongue, which they had almost forgotten."

This testimony is sufficient to show that there had been contact between Zuñi and Indians of Mexico in the earliest historical period, and further communication was had when the Spanish explorers who followed Coronado and Espejo in the sixteenth and seventeenth centuries wended their way, with Indian companions, from the Valley of Mexico to the far-off Pueblo country in the north. Indeed, there is positive evidence that a considerable body of the earliest New Mexico colonists was composed of Tlascalan or other Mexican Indians who were established in a ward of Santa Fe known as Analco, and that San Miguel Chapel, still in use, was erected for them.

If further evidence of the contact were needed, it might be added that during the progress of excavation by the Museum of the American Indian, Heye Foundation, of the ruined Zuñi pueblo of Hawikuh, with its church and monastery, there were recovered various objects introduced from Mexico, most of them of European origin and of the mission period of 1629-1670; but copper bells of Mexican Indian manufacture and an earthenware pot-cover, painted in typically Mexican Indian designs, have also been found.

So much for theory, which thus far seems to be sufficiently well substantiated to warrant belief in the finding of the terracotta heads in the Zuñi church.

But fortunately the writer knew the missionary, whose name the Indian agent could not recall, as a lady who reestablished the Presbyterian mission and school at Zuñi in the autumn of 1888, spending many years there. And, even more fortunately, she is still a resident of New Mexico, and possessed of an excellent memory even after a lapse of 31 years. The result of a letter of inquiry shed such light on the reputed finds as to dissipate completely the story of the agent as well as the theory built on his statement, which we do not question was made in the utmost good faith.

The cause of all the contention is due to a reprobate relation of Pálowahtiwa, the brother, by adoption, of the late Frank Hamilton Cushing, who, as an ethnologist of the Smithsonian Institution, spent nearly five years at Zuñi, from 1879 to 1884. When Cushing finally left Zuñi during the operations of the Hemenway Archeological Expedition in 1888, it was with the expectation of returning; but the opportunity never came, and his belongings remained in the home he had built, only to be looted long afterward by the native of whom mention has been made.

This Indian one day brought to the Presbyterian missionary, for sale, a box of little terracotta heads which he claimed to have

found in an ancient ruin near the farming village of Ojo Caliente, which corresponds in locality with the ancient Hawikuh. Knowing of the existence of this ruin, and fully believing the Indian's plausible yarn, the missionary purchased the lot of objects, and believes that others may have been given or sold to the agent; but never to her knowledge has the cornerstone of the church been disturbed.

Wishing to have an expression of expert opinion of the "find," the missionary took most of the specimens to the Smithsonian Institution at Washington in 1893, when she went east to attend the World's Exposition in Chicago. Here she met Cushing, to whom she gave an account of how, when, and where she had procured the heads, and who recalled that they had been given to him "by a visiting professor," whom I surmise to have been the late Adolf F. Bandelier. The visitor had obtained the objects in Mexico, and on his way home had stopped at Zuñi and left them with his host. The missionary, now learning of their true ownership for the first time, left the little collection with Cushing, expressing her regret that it was not possible to return also the rest of his belongings which she feared were being disposed of in the same manner. Indeed, during the following autumn the family of the man who had sold the little heads to the missionary offered other articles which evidently belonged to Cushing, which she, of course, refused to purchase.

During the ensuing winter or in the following spring, the Indian agent visited Zuñi, and on "displaying formidable weapons" the Indians thought it discreet to evade a charge of theft by placing in the agent's hands the rest of the plunder, thereby unconsciously lighting the fuse that, after more than thirty years, has resulted in the explosion of a very pretty theory, built on the most plausible testimony, respecting the origin of the terracotta heads.

All of which goes to show how easy it is for the student to skid on the road to science, even after using every care.

THE NEED OF AN INTERNATIONAL MIND

By Professor R. D. CARMICHAEL
UNIVERSITY OF ILLINOIS

WAS it H. G. Wells who insisted upon the fact that the political boundaries of Europe are still essentially those which belong to the horse age of transportation whereas we are now living in an age of travel by means of the locomotive, the automobile and the airplane? It is now so obvious that people separated by a hundred miles of space are in fact much nearer together than they were even fifty years ago that one would not insist upon the point were it not for the pregnant corollary which follows from the fact. The progress of invention has greatly narrowed the effective size of the earth as a home for man. The various peoples of the earth are physically much closer together than heretofore. There is an intimate interweaving of their interests. What affects one now reacts upon another more intimately than our fathers could have anticipated even a generation ago. Notwithstanding the separations and antagonisms among the parts of this general human society the whole has become more organically connected than ever before. All mankind is tied together physically in a way which no one a hundred years ago could have considered possible. All this is a commonplace of current thought.

But we are not united intellectually. The progress of invention has brought us together physically. But we have failed to make a corresponding and sufficient advance intellectually; and we have particularly failed to do so spiritually. In an earlier time there was a certain unity of intellectual life in Europe centered about the church and the Bible. The great Hebrew literature contained in the latter furnished a significant and common part of the culture of the time and held peoples together by the bond of a common intellectual and spiritual possession. H. G. Wells has urged the desirability of creating a new Bible of civilization to give to the modern world a like common intellectual and spiritual possession. Whatever might be the value of such a common modern Bible of civilization, if it were formed, we can not say; it is clear that there is no prospect of the immediate construction of one.

But there is an important thought which may be symbolized for us by the imagined existence of such a work. Let us think for a moment what its value might be. If such a compact and comprehensive Bible of civilization were universally distributed and if

its materials were so selected as to be received with confidence everywhere, it would give to all men a certain common intellectual and spiritual possession, a certain common ground on which their association could be built, a certain common starting-point from which their thought could proceed, and consequently a certain commensurability in the conclusions reached which would go far toward making it possible for them to understand each other better than they do at present. Such a work would do much to remove the uncalled-for differences which separate peoples and needlessly set them against each other. It would give them a common interest of an intimate sort.

But there is certainly no prospect of an immediate realization of such benefits through the construction of a universal Bible of civilization.

These considerations leave us face to face with an important question, the answer to which they do not help us to attain. What shall we do to lead to the development of an international mind, a common view of truth and humankind, such as will contribute best to the progress of an enduring civilization based on the nobler qualities of man? What should be the starting-point from which we may proceed to realize the goods which we are considering? This is a question which has been asked by many people. Where shall we turn for an answer to it?

In the present disturbed condition of the world the question is more insistent than ever and it clamors still more loudly for an answer. The immediate and permanent international reality finds expression in the economic sphere, in forms of international workmen's associations, in finance and commerce and even in the less obtrusive internationalism of science and religion and art. Varied national interests are involved in the problem and they often clash with one another. But there is one place where the current nationalisms need not interfere with the development of an international mind. This is in the domain of pure thought where the endeavor is made to reach a systematic and synthetic order of truth and to afford a general view of the world of human thought within the limits of a rigorous scientific knowledge. It is inevitable that we shall think of this as the place in human thought at which it will be most profitable to labor toward the formation of an international mind, because it is here that success is most likely.

Even when we turn to the domain of science, where thought is more exact than elsewhere, we find difficulties in the way of an intellectual synthesis. Contemporary intellectual life is not unilateral in any of its domains. Science at present is many-sided. Its diversities increase. New chapters are being added to all the

sciences. The difficulties of an integral view are increasing; and the need for achieving it is growing at the same time. Success can not be expected except through organized and careful effort; and such labor will need an organ and a clearing-house for ideas. The work can be done successfully in no other way. There must be a broad and open forum for the analysis of interesting and debated questions by those best qualified to treat them.

Fortunately, *Scientia*, the international review of scientific synthesis published at Milan, Italy, offers just such a forum for discussions which contribute to the philosophic synthesizing of science and the intellectual fraternization of peoples as is needed at the present time. One principal purpose for the writing of the present article is to assist in promoting those ideals for which *Scientia* stands, and to further in some measure the inspiring program which the editors of that unique journal have formulated.[1] Its world-wide distribution has exceeded the expectations of the editors and has encouraged them to promote a campaign for its larger distribution and for the wider diffusion of the spirit which animates it. The entire contents are accessible to those who read French, since the articles of those who write in other languages are printed in French as well as in the language of the author.[2]

The ideal set by the editors of this journal for promoting the philosophic synthesis of scientific truth and the development of a common international basis for philosophic interpretation is of such character as to merit the attention of all those who are concerned with the broader aspects of the development of scientific thought. The character of this ideal may be seen from an example of the editors' practice. Let us notice the nature of the demands which they are making upon authors who have been asked to contribute to an international symposium upon the theory of relativity. (Perhaps I may give a brief account of this without laying myself open to the charge of divulging what should be kept private.)

The present state of the theory of relativity, the degree of maturity which it has reached, the extensive and varied development of it which has been set forth in so large a literature, the doubts and difficulties which it has encountered, the enthusiasms which it has engendered, the difficult form which much of the exposition of it has taken, its intimate relations with the deepest realities accessible to investigation—all these render desirable a coordinated international inquiry into the theory. The inquiry which the edi-

[1] American subscribers can conveniently purchase *Scientia* through Messrs. Williams & Wilkins, Mount Royal and Guilford Avenues, Baltimore, Maryland, at ten dollars per year (twelve issues).

[2] Among recent contributors are the following Americans: W. D. MacMillan, S. Nearing, L. E. Dickson, W. S. Adams.

tors propose has at the same time the following two fundamental purposes: (a) to submit the theory to a careful and profound objective examination in order to bring to light its points of weakness and to suggest the revisions necessary to remove these objections; (b) to perform a work of clarification by seeking to render either the theory in its entirety or in one or another of its fundamental points or else the principles which constitute its foundations or the results to which it leads, by seeking to render these accessible to all learned persons with a philosophic tendency and in particular to those who are not mathematicians.

With these aims in mind the contributors are to choose their subjects and to adopt methods of exposition which permit the development of the thought without recourse to technical mathematical ideas or mathematical formulae. It is, then, necessary for the author to express himself solely in ordinary language and in a manner which is accessible and clear to those who are attracted to the theory and yet are without the technical equipment by means of which the investigator carries on his work. By this means the contributors are to lead the reader through to the fundamental conceptions of the theory and to an understanding of its physical significance.

It is thus seen that the ideal of scientific synthesis which *Scientia* seeks to realize demands that the broader conceptions of scientific thought shall be made accessible to all cultivated persons with a tendency to philosophic interpretation. The work to be achieved is greatly needed. It must contribute effectively to the formation of an international mind. It deals with that part of our intellectual life in which there is most hope for some uniformity of philosophic interpretation, namely, that part which has to do with science. The diversity of individuality will remain, as it should; but the active association of minds devoted to a philosophic synthesis of science will do much to create in this field the common atmosphere and common foundation which are essential to a broad conception of the import and meaning of nature and natural forces.

Those who feel the need of a common meeting ground for the thinkers of different countries and for the workers in different fields perhaps do not at present constitute a large host, but they form a mighty company on whom much of the further progress of truth depends. The more profound wisdom of mankind must not be parceled out by national boundaries nor by barriers which separate one portion of thought from another. Science is now cultivated with the greatest success and earnestness, both in its principles and in its applications, without any direct reference or adaptation to philosophical or religious interpretation, and it makes its way freely

through every part of the earth and the sky and penetrates to the substances below the surface and into the depths of the sea. Every unexplored region attracts the intellectual traveler with the fascination of the unknown and leads him to spare neither peril nor sacrifice if these may aid him in throwing light into what might otherwise involve a scientific mystery. This disinterested and depersonalized investigation must proceed unabated and every dark corner must be searched for its hidden truth.

The partial knowledge which is gathered in this way by various workers through all countries and in all divisions of scientific inquiry should in some way be brought to the focus of philosophic interpretation and synthesized into an organic unity whose power may be felt in the spiritual life of mankind. Here is a work which will require the pooling of all our intellectual and spiritual resources. In some way or other the partial views of things must be united into a whole. We need a philosophy which seeks to know the very essence of science, an astronomy which goes forth to discover the eternal mysteries of infinite space, a physics and chemistry which reveal the secret of the infinitely small atom by means of the dispersive power of the intellect, and a psychobiology which can lift the veil from the mystery of life and spirit; but above all we need that synthetic view of nature and man which contemplates them in their entirety and understands a little of the meaning of the universe. As a first step toward this we require a broad synthesis of scientific truth along philosophic lines.

The devotion of a few thinkers everywhere to the achievement of this high ideal will do much toward the development of the international mind which seems to us to be so much needed at the present time. Among the separate sciences of the more exact sort there is and has been for some time a large measure of agreement which is not hindered by international boundaries; but it seems that no great success has yet been achieved toward the uniting of these partial international minds into a more comprehensive one which shall embrace all the more profound concerns of our humankind. It is on the importance of the latter that we place our present emphasis.

The task is difficult, but the difficulty does not seem to be too great for success. It is perhaps necessary to begin at the right place. Certain intellectual activities are individual in their character or belong at most to a restricted group of people. This is the more true as they pertain more to the meaning and significance either of things or of thoughts. But in a range of thought where there is so much agreement among thinkers as to the facts and the principal laws as there is in the natural and mathematical sciences,

it seems that an understanding of meaning and significance could be so clearly conceived that there would be a fair agreement on some of the matters of most profound philosophic import. That there is great difficulty in attaining such a measure of clarity and such a comprehension of the meaning of things must have been apparent to every thinker in our age who has discussed these problems intimately with a group of thinkers representing the several sciences and thus moved by the varying traditions which animate or restrict the attention of workers in the different fields But success should not be impossible It is a matter of great human value and fraught with large possibilities for the development of science itself It is a work to inspire the best efforts of the greater intellects.

Among the publications which at present foster such work and further such interests *Scientia* appears to me to hold a unique place Contributions to the same purpose are made by other periodicals and the cause is advanced by a number of individual thinkers But this ideal and this goal seem to be in the forefront of attention with the editors of *Scientia* and they are making a contribution toward an international cooperation in scientific work which deserves the hearty support of every one who believes in their inspiring program of the philosophic synthesis of science and the intellectual fraternization of peoples

FOUR GENERATIONS OF MEMORABLE BOTANISTS

By Professor WILLIAM TRELEASE
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ONE midsummer evening last year, as I sat on the terrace before Madame Augustin de Candolle's residence overlooking the beautiful estate of Le Vallon, where France and Switzerland meet along the lower stretches of the picturesque Arve, it occurred to me that no American journal had brought to my notice the passing almost simultaneously of two of the four generations of botanists whose distinguished name our hostess bears Augustin de Candolle died on the ninth of May, 1920 Only a few months earlier, he had written to express his appreciation of a note of sympathy addressed to his mother after the passing of his father, Casimir de Candolle, on the third of October, 1918, a note that arrived only after her own eyes had closed for the last time

As Madame de Candolle told me of the consolation that her husband found during his own last stricken days in rereading the halting lines that affection and veneration had dictated in reply to his letter, I recalled that a quarter of a century earlier Casimir de Candolle in his characteristic quiet and polite but positive manner had turned to me, while we were dining, with the astonishing statement, "You knew my father." No protestation that the acquaintance was only that of a neophyte asking the aid of a master could mask the fact that the response of the master was an exemplification of the kindly helpfulness shown by four generations to whom scientific assets, easy circumstances and rare learning crystallized into its unusual concomitant—wisdom, carried the obligation of personal helpfulness as well as of professional productiveness

This spirit was exemplified when I last saw Casimir and Augustin together, while the war-cloud was gathering, critically approving purchases from a list of new books; for the family policy of two preceding generations was continued, that no book of real botanical value should be sought in vain in the Candollean library.

It was shown in quite a different way, when, after enjoying months of hospitality such as no endowed institution could surpass and few equal either in spirit or resources, I said good-bye forever to Casimir de Candolle as he handed the last of my manuscript cases into a cab at the Molard, to which he had insisted on accompanying me through a December rain from the ancestral home in the Cour de Saint Pierre on top of the overhanging hill.

Quite unexpectedly my own later studies have been directed along lines earlier mapped, and well mapped, by the first three of these four generations of Swiss botanists, each of whom left his work complete for its day: the mistletoes, oaks and peppers. The Candollean herbarium, therefore, has become a shrine of what is classic for all future students of these groups It contains in compact form the chief materials—of which these are a small part—to which one of the world's greatest publications, the Prodromus Systematis Naturalis Regni Vegetabilis, perpetually refers for verification of facts imperfectly expressed in even the most precise and methodically chosen words. Though my interest had not then touched his own specialty, Casimir de Candolle was a helpful guide as I reviewed those of his father and grandfather

Geneva is justly proud of the achievements and the personality of its citizens. For centuries it has been the refuge of those whose thought revolted against being unduly curbed A decade ago, the bastions of its abandoned fortifications were consecrated to relief portraits of the great leaders of religious reformation. The brow of its hill along the river is surmounted by the cathedral of Saint Pierre, beside which stands Knox's humble chapel.

It was on the square fronting these churches that the father of Augustin-Pyramus de Candolle established the home that the latter devoted in large part to the accommodation of library and herbarium, and that for two generations now has been turned over entirely to these material equipments of a scientific impulse which has led to self-imposed industry such as money rarely buys. Here almost up to the day of his death Casimir de Candolle was to be found, pleasurably if almost hopelessly trying to bring the chosen work of a lifetime to conclusion; just as his father and his grandfather had striven to produce that great desideratum of all time, a Flora of the world—to be complete for its day and generation.

The de Candolle family is originally a French family. In the seventeenth century it had fled from the restraints of Provence to the religious freedom of Geneva. Still, it would be wrong to say that the botanists of this family are other than French Swiss, with whatever that expression may imply, for it was more than a century later that the initial of the four generations of botanists who have made it famous was born.

These men were not narrow-minded specialists, trained and educated within narrow bounds. Each, in his day, was a liberally educated public-spirited citizen of the city and the canton. They naturally differed in manifestation of the fundamentals of good citizenship, each responding to the times in which he lived; but one love of nature and of science, which is its organized method and expression, was transmitted from father to son.

If this has proved less appealing to the latest generation, the fact is easily understood in view of the more sedentary less materially constructive phase into which botany seems gradually to be passing, and of the increasing lure of constructive world activities.

Of Casimir de Candolle's sons, the elder, General Raymond de Candolle, of the British Army, an eminent engineer, with a distinguished record as a great railroad builder before his participation in the World War, seems not to have cared to follow in the scientific footsteps of his father and grandfather; and the younger, Augustin, found active legal and diplomatic activities almost if not quite a balance for the quieter and more withdrawn activities in which his ancestors so delighted, but to which he returned at the end

That Augustin's sons, developing young men of charming personality and brilliant mentality, do not appear to be at all drawn to lives of botanical activity must be admitted with recognition of the remarkable fact that the priceless family treasure of library and herbarium have been entrusted by them and their family to the keeping of the city of Geneva, where, at the botanical garden on the shores of the beautiful lake, facing the Alps with Mont Blanc towering in the distance, they perpetuate the Candollean tradition that they belong not to individuals but to the scientific world, for which four generations of investigators have labored assiduously in varied fields of botany.

Except for the newer biologic studies comprised in a general way under the name ecology, no botanist progresses far in any branch of botany without encountering the name de Candolle in connection with its fundamentals, whether his interest be in morphology, physiology, mycology, monographic descriptions, the geographic distribution of plants, or their classification along lines of true relationship, once called a natural system and now called a phylogenetic system.

Augustin-Pyramus de Candolle
(1778-1841)

Augustin-Pyramus de Candolle, the founder of the Swiss line and of its chain of botanists, is claimed by Sachs as French. This seems hardly accurate, for he was born in Geneva and was twenty years old and well grounded in the humanities when, his canton becoming politically French, he began his active life as a student of medicine and an original worker in botany at Paris.

The road to productivity in science was then less than to-day what his native language so expressively calls "le chemin des écoliers." When he was only twenty-one years old he began, and

AUGUSTIN-PYRAMUS DE CANDOLLE

completed in five years, the publication of the finest treatise yet produced on succulent plants. At twenty-six he had written on the medicinal properties of plants and had started a Flora of France. At twenty-eight he discovered the modifiable rhythmic periodicity of the "sleep" of plants. He lectured on the field of what had become his passion in the Collège de France, and his breadth of interest and talent were such and so fully recognized that for a half dozen years he served as a government explorer in botany and agriculture between the North Sea and the Mediterranean

If the Napoleonic fortunes had not changed, it is quite possible that he might have remained bodily, as he was ancestrally, French, and that Geneva's loss might have proved the lasting gain of the mother country through the addition of his distinguished life and line to the many of which Paris is justly proud. But it was not so ordained. A chair of botany was established for him in the city of his birth, and from early mid-age until his death, at the age of sixty-three, he was again a Genevese; laying fascinatingly the foundation of a general morphology of plants; exemplifying their natural classification in a botanical garden and expounding its principles; initiating the proposed summary of the known flora of the world, modestly and understandingly called a Prodromus, and bringing together the great herbarium and library which he bequeathed to his son Alphonse with the tradition that they were public rather than private collections and that they and the Prodromus were to continue to grow

From bust and medallion one judges that Augustin-Pyramus de Candolle was a large man, strong-featured, full of energy, decisive. In his engraved portrait, one sees the thoughtful, learned scholar. Both impressions seem to be grounded in his life as a constructive citizen and a producer and path-finder in his chosen field of scientific activity.

Alphonse de Candolle
(1806-1893)

Alphonse de Candolle (Alphonse-Louis-Pierre-Pyramus), unlike his father, inherited a trust for science. On a generous education he built a botanical career paralleling that of his father. Born in Paris, but a Genevese from his eighth year until his death, except for a distinguished preliminary legal practice he collaborated with his father on the Prodromus until forced to carry it on at first alone and then with his son Casimir as coadjutor. Alphonse de Candolle's interests were unusually broad. In his turn he did talented monographic work, but this did not hold his hand from physiological experimentation of a high order, and he sketched unusually well the

ALPHONSE DE CANDOLLE

principles of plant geography and was well acquainted with paleobotany.

If, perhaps, less in the ordinary public eye than his father, Alphonse de Candolle was a force in the community and equally known and equally appreciated by all those to whom the amiable science was at once vocation and avocation. In his turn he held the professorship established for his father. His first publication, at the age of eighteen, was on a fungus. His broader tastes had declared themselves before he was thirty years old. His ethnobotanical study of the source of origin and the enforced migrations

of cultivated plants still stands as a classic. No more readable or cleaner-cut analysis of phytography and its methods seems likely ever to be made than he presents in "La phytographie, ou l'art de décrire les plantes"

As he had worked at his father's side during the earlier part of his life, so he had for the collaborator of his later years his son Casimir Together they added to both library and herbarium Together they carried the Prodromus, begun in 1824, to a point when, after half a century, its completion along the original lines seemed no longer feasible or desirable. Together, they instituted on new lines, five years later, a series of Monographiae Phanerogamarum, in which, as in the Prodromus, cooperative work by others was welcomed.

Alphonse de Candolle sometimes is spoken of as "le magnifique de Candolle." While his repute as a botanist was growing—and his prestige was such that admittance to his scientific circle was equivalent to recognition among the "Who's Who in Botany" of his day—worldly affairs prospered under his wise administration

As with his father, engraved portrait and bust present to the eye of a stranger different aspects of Alphonse de Candolle, both evidently characteristic of the man. In the one, the steady-going judicial man of affairs and of science is to be seen; in the other shines that alertness which led Asa Gray to say to me once that the intuitive genius of de Candolle was unequaled.

Casimir de Candolle
(1836-1918)

Casimir de Candolle (Anne-Casimir-Pyramus) exemplified remarkably the influence in human life of heredity, education, environment and a sense of duty. Born in Geneva, his affections crossed the channel; his wife, a community worker of rare devotion and energy, was Swiss-English, and his children were born in England, though his residence was in Switzerland. From the first his bent was along the line of science, as his grandfather's had been along that of history and his father's in jurisprudence. Generously trained in mathematics, chemistry and physics, he came on the stage when Naegeli's observations and Sachs' experiments were opening up a line of botanical study well worthy of exploration and still being fruitfully exploited by workers of physico-chemical aptness.

Phyllotaxis, deviation from typical structure, the significance of the anatomy of various members of the plant, the structure and movement of the leaves of Venus' fly trap, the latent life of ungerminated seeds: these and numerous other phases of morphology and physiology are among the things that caught his observant attention and that he elucidated,—always from the proximal physico-

CASIMIR DE CANDOLLE

chemical or mathematical rather than from the ultimate or teleological viewpoint. One might suppose that with his taste and education he would not have escaped the insistence of such problems.

His first publication, at the age of twenty-four, was based on a study of the generation and regeneration of cork that he made while inspecting family properties in the south. As with his father and his grandfather, the Prodromus proved a pivot in his activities, and, exemplifying the nature of such undertaking, one small fragment of its topic absorbed the greater part of his long life. In 1864 he published in a preliminary way on the enormous family Piperaceae, which five years later, when he was only thirty-three years old, he monographed for the Prodromus in its entirety so far as the materials of the day permitted. From the age of twenty-eight until his death at the age of eighty-two, hardly a line, with exception of Peperomia studies by Henschen and Dahlstedt, was published on this great group of tropical plants except from his pen. Since his passing, several regional papers on it, written by him, have been published, a memoir on the morphology of the Piperaceae exists in manuscript; and a key to its many species, to which much of the keen energy of his latest years had been given, fittingly forms the major part of the first volume of a new journal, *Candollea,* dedicated to the illustrious family whose name it bears.

In manner, Casimir de Candolle exemplified perfectly the polished courteous kindly gentleman. He was a man of positive con-

victions; but just as in his scientific work he was given to a deliberate weighing of the facts under his eye and quite uncontroversial as to their teleological bearing, so in his daily relations he saw and did what it was his to do but did not enter into fruitless acrimonious debates. Perhaps the most caustic remark that I ever heard him make was once, when I had expressed surprise at the rapid growth of our big-trees (Sequoia) in Geneva, and he said "Yes, but I sometimes think that they are too frequently planted"—an opinion the weight of which has been growing on me ever since, though I experience a sort of horror whenever I see one of them laid low

As with the preceding generations, and to a greater degree, bust and portrait are discordant in the case of Casimir de Candolle. The sculptor seems to me to have missed the truest expression of his character—just as in the other cases the plastic art has brought this out; but, though less kindly than was his wont, perhaps, he looked into the camera with the clear-eyed directness that, with kindliness, was his most marked personal trait.

Augustin de Candolle
(1868-1920)

Augustin de Candolle (Richard-Emile-Augustin) was born in England, and his secondary education was English His predilection was for public service and his training was in the law, with the broad background of general culture lacking to none of his family. Though he did not lose these professional and humanistic interests, he accorded much of his scant fifty years of life to the traditional calling of the family, to which, after his father's death, he fully yielded. Somewhat as the mathematical trend of his father's mind had led to conservatism in certain directions, the judicial training of Augustin, like that of his grandfather, equally led to carefully weighed conclusions.

As his father had done, Augustin felt the appeal of certain morphological and physiological phenomena, and he published on both. His first papers, at the age of twenty-seven, were physiological; but four years later he had begun on methodical descriptive work. Cooperating with his father in publishing the Monographiae, and confronted with the daily demands on library and herbarium, he naturally if not inevitably found in the field of descriptive botany the restful task of such time as his arduous duties as British consul during the period of the war yielded.

That he did not undertake to monograph large families is readily understandable; that he did well the sometimes more difficult work of naming authoritatively material from far lands falling within groups that he had not monographed speaks for the breadth of interest and of talent begotten by his unsurpassed environment.

AUGUSTIN DE CANDOLLE

Not unfittingly he was called on for a period of years to preside over the Société botanique, and over the broader Société de physique et d'histoire naturelle of Geneva

Less French and more English, perhaps, less a devoted specialist, more a man of the active world, Augustin de Candolle was yet an excellent botanist. To the end of his short life he maintained and exemplified the traditions of a family of botanists unbroken for four generations, who will live far into the future as vital forces in the science to which their lives and fortunes were devoted.

Their memory will be kept green so long as botanists continue to be attracted to Geneva by the municipality's monumental collections of plants,—formed by de Lessert, Moricand, Burnat and Boissier, to which, in fulfilment perhaps of its founder's hope if not injunction of a century ago, the Candollean herbarium and library are now added through the joint generosity of the family who brought them together and the city which stands so well to the fore in the history of religious liberty and scientific advancement.

In the halls of the University of Geneva are busts, which, even though they lack the expressiveness that only the human eye carries and which bronze can not seize, will give pause for many generations to the visitor who tries through such imperfect aids to visualize the personality of these generations of great men who have joined their strength to that of others in making Geneva great among the cities of the world.

THE NEXT SCIENCE

By Professor ARLAND D. WEEKS

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The place of science is now well established. To the application of scientific knowledge are ascribed increase of wealth, improved health conditions, perfected means of communication and transportation, and a multitude of practical conveniences The nineteenth century was known as a century of science, and the past two decades have seen still further scientific achievement. From the slight beginnings of realism and science of the later Middle Ages an increasing amount of effort and attention has been given to scientific investigation and with noteworthy results.

It would be a mistake, however, to regard the past century or more as a thoroughly scientific era. Science is but one phenomenon in the total social mind of the present time Science and barbarism may exist in the same society, as witness Europe of the past decade, even in the same individual. It can not be claimed that science has conquered the modern world Its achievements are many and conspicuous, but large sections of life appear to lie outside of its jurisdiction as at present described.

It can not be claimed that the spirit and method of science have made a conquest of legislation. Fact finding and scientific impartiality are not yet synonymous with legislation. In international relations the functioning mind appears to be at a stage comparable to that of the mind preceding the scientific era.

The failure to conserve natural wealth and to utilize the potential resources of society is one of the weaknesses of civilization. Water power, coal, forests, structures destroyed by fire, ill health and other items of waste testify to the failure of science to keep the social house in order Poverty and deprivation exist in modern nations. Unemployment is common. The normal state of modern society seems to be one of abnormality with reference to employment.

How short is the arm of science may be observed in the case of scientific specialization. Consider dyes. Dyes may be regarded merely from a chemical viewpoint. The science of dyes is a well-marked-off field within the large field of the science of chemistry. So far as dyes fall within chemical science these substances are mostly for the coloring of fabrics, but the human significance of dyes transcends the laboratory. The coloring of fabrics plays a

large social rôle. The social bearings of the substances we call dyes are far-reaching and hint at possible science quite outside of the ordinary. But the immediate science of dyes stops with chemical traits It could not be claimed that society is fully scientific with reference to dyes until it recognizes the social rôle and ultimate consequences of dyes as well as the actual chemistry of dyes

The same point of view may be taken with reference to almost any substance The science of explosives is a technical and circumscribed branch of knowledge when confined merely to chemistry. Explosives as a social fact invite to a superscience still rather beyond our age. Indeed, perhaps the times call for superscientists whose vision, not limited to the physical or chemical qualities of materials, shall extend to the human scene in all its fullness—to welfare in the concrete, and of the widest social reference

A like separation of technical science from human circumstances and considerations is illustrated in the profuse manufacture of unnecessarily fragile and perishable articles of commerce A large amount of raw material and human labor is wasted through being used in the manufacture of wavy glass, short length bed sheets, acid-distended leather goods and deceptive textiles To be sure, we set the scientific detector on the trail of the scientific cheat, although often too late

Are we to depreciate science because of its shortcomings? Impressed with the failure of science to bring the millennium, should we abandon science and return to the former humanistic learning, giving Latin its earlier place and closing the physical laboratory?

The challenge of the times is not to less science but to more Science has laid the foundation upon which may be erected a body of knowledge as yet merely hinted at in psychology, sociology, economics, ethics and public affairs With reference to the social and human sciences, we are now about where the medieval schoolmen were when Roger Bacon was languishing in a dungeon for being convicted of chemical experimentation This is a scientific age—to an extent. It is prevailingly non-scientific The social, political, financial and international questions to which no answers are at hand would convince the most skeptical that there are fields of potential science relatively undeveloped We are of the Middle Ages in our point of view regarding social research and experimentation.

Certain obstacles stand in the way of extending science to the social field. The expense of fact-gathering for the new sciences is to be noted. The development of physical science was delayed because of costs. It was easier and cheaper to teach Latin than to present physics, bacteriology or chemistry. The compilation of

scientific knowledge is tedious and expensive. A classical college could be supported for a sum that would scarcely maintain a single department of science in a modern high school. Physical science has always had to struggle against expense and difficulties of procedure. In the case of the projected social and vital sciences, the cost of fact-gathering and of reaching a high degree of probability, of research and experimentation, would no doubt exceed that with which we are familiar in the physical sciences.

Not only is there a financial burden to be assumed in the building up of a comprehensive social science, but there is an antagonism to the free use of hypothesis like that which existed three centuries ago to impede the development of natural science. A large majority of people to-day would feel much the same horror toward research and experimentation touching social questions as was felt by the bulk of population three centuries ago toward new views of nature

The study of natural and physical science has been successful because for a century methods have been employed that lead to new knowledge. The scientific student or investigator assumes that new knowledge lies ahead; he assumes that the existing state of a science is only a passing stage of development. His course is to work forward on the basis of established positions and to renounce theories and convictions whenever the evidence demands renunciation.

The methods of scientific research conform to the outline laid down by Huxley. Observation, comparison, generalization and verification constitute the main steps of procedure, whether the research is to establish the relation of bumblebees to the production of red clover seed or to arrive at a cure for a disease. Francis Bacon's conception of scientific procedure contemplated an exhaustive and minute observation of natural phenomena prior to hypothesis. Modern science short-cuts the observation by proceeding under ingenious guesses which if successful bring to speedy end a procedure of fact-gathering which by the Baconian method would be hopelessly burdensome.

To equal in the social and civic field the successes of physical and mechanical science of the past few generations will require a transfer to this field of the essential methods of scientific research. Observation, comparison, generalization and verification must be applied with the freedom of research if the final product of social, economic and political science is to bear favorable comparison with the fruits of present scientific investigation.

Utilizing the methods of existing science the new science will supplement and tend to complete the imperfect structure of organ-

ized knowledge. The past century may be regarded as having prepared the foundations for a many-storied building of knowledge, but as having left the building with raw walls scarcely above street level. Natural, physical and mechanical science is but a beginning, for there remain the further application of present science to human welfare and the organizing of distinctly humanistic sciences—forms of knowledge identified with superior forces and behavior.

The spirit of scientific inquiry is not less essential than method. Calmness, patience, teachableness, fairness—these are needful. The true scientist expects to prove all things, to be found in error, to go forward to unforeseen conclusions. Can the new science do otherwise? Rootedness of ideas and proscription of inquiry have no more place in social science than in metallurgy or microbiology. And tentative theories and even bold guesses, valid in medical and in electrical science, have corresponding, though possibly but temporary utility, in formulating the humanistic science of the future.

The new scientist, or superscientist, whose wisdom will include that of making good use of what he knows, will be an adept in working his way among the theories and the convictions of his fellows without being chafed and irritated. The present-day scientist is conscious of variant opinions and is glad to explore these and confer with their advocates. Political and social knowledge having any claim to serious consideration can not be built up by persons who insist upon running only with others of the same opinions. There is, it is true, a satisfaction in the hearing of one's own views rehearsed and in being reinoculated with one's own germs, but this pleasure may be made to give way to the delights of discovery.

I have touched in briefest outline some of the shortcomings of present-day science and indicated the field wherein might be formed a body of scientific knowledge characterized by specific social reference and utility. By no means should we turn in our tracks and go back to the exhausted cultures of the classical past, though science has been disappointing. Nor should we judge the case for science by the modern specialist who is equally zealous when engaged on the chemistry of Christmas candles or the chemistry of colloids and gases for the destruction of future foreign populations. A beginning of science has been made. It remains to press on in the scientific spirit, with purpose to bring within the realm of verification a great territory still given over to credulity, prejudice and fanaticism.

To illustrate the point of division between the old science and the new let us consider John Burroughs. I yield to no one in my

admiration of John Burroughs, but in the limitations of his field of observation there was something that speaks of the times. He was a close observer of the birds, plants and animals in the neighborhood of his Hudson River farm. As a grape grower and a shipper of grapes to the New York market his experiences resembled those of some of his neighbors, who instead of receiving a check in payment for fruit shipped, received, instead, a bill for freight and selling charges. Burroughs finally gave up some of his vineyard. One may read every book that John Burroughs wrote and find that while the biography of Jenny Wren is complete, there is a total absence of scientific curiosity with reference to the grape market.

As great as are the achievements of modern science, still greater achievements are conceivable. It would be grievous error to assume that there is little left for scientific exploration. Some have even argued that materialistic science has made the human race no happier than before, in which event the hope of the future lies with more science, or different, or both.

One can scarcely open a newspaper without chancing upon topics that suggest more than a day's work for the future social scientist. I quote several titles from the November (1923) *Nation's Business*, published by the United States Chamber of Commerce: "It costs too much to sell food," "America may abolish poverty," "The railroads ten years from now," "Remaking the new tariff to fit," "Human nature in business," "Recent federal trade cases," "Can't we carry freight to your doors?" Not one of these topics fails to challenge the investigator. The popular treatment of topics of this class looks in the direction of science, but rarely achieves authority and impartiality. Society has yet to provide staff and resources for genuinely scientific exploration of contemporary social problems and conditions.

The spirit of inquiry which has been a feature of the past century of science has a rich territory in matters that come close to men's business and happiness. Physical science can not resolve the tangle in which the world finds itself; and impulse, reaction and incantations are out of place. The Newtons, Keplers, Darwins, Pascals and Edisons of the to-morrow of science will perforce enter the domain of psychological and social phenomena and develop techniques not less pleasingly scientific than the acknowledged skills associated with the test tube, the compound microscope and the laboratory of the admirably competent but morally and socially circumscribed sciences of material things.

IMMIGRATION AND THE DECLINING BIRTHRATE

By Dr. MAURICE R. DAVIE
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SINCE General Francis A. Walker published his article on "Immigration and degradation" about thirty years ago, it has been rather generally believed among students of the subject that immigration has not increased the population of the nation. According to this point of view, immigration has amounted not to a reinforcement of our population but to a replacement of native by foreign stock. Indeed, it is claimed by one writer that the United States would have a larger population to-day if there had been no immigration since 1820. Some such view of the effect of immigration on population is to be found in most books on immigration, and to-day it is being stressed as an argument in favor of restriction.

The origin of this opinion goes back to one Elkanah Watson, who in 1815 wrote a brief statement entitled, "A view of the progress of the population of the United States." He had been impressed by the rapid growth of population during the two decades following the first enumeration in 1790, and on the supposition that numbers would continue to increase in the same ratio he predicted what the total population would be at each succeeding census up to 1900. He himself noted the actual results until 1840, and when he compared them with his earlier estimates he found that the two sets of figures at each census year practically coincided. His estimates for the following decades, however, proved to be much in excess, and increasingly so, with the widest discrepancy appearing in 1900. Whereas he had predicted a population of one hundred million in 1900, the census report showed only seventy-five million. It is to be noted that immigration at the time when Watson wrote was inconsiderable in amount and that he did not foresee the great influx of immigrants that occurred later. He expected the increase of population to come from excess of births over deaths. In spite of the fact that many million immigrants have arrived, the total population of the United States at each decade since 1840, with one minor exception, has failed to reach the figure which Watson had predicted.

The following table shows these results:

Watson's Estimates		Actual Result	Watson's Excess Over Actual Numbers	Immigants Preceding Decade
1820	9,625,734	9,638,453	12,719	(No data until 1820)
1830	12,833,645	12,866,020	32,375	151,824
1840	17,116,526	17,069,453	47,073	599,125
1850	23,185,368	23,191,876	6,508	1,753,274
1860	31,753,824	31,443,321	310,503	2,571,036
1870	42,328,432	38,558,371	3,770,061	2,377,279
1880	56,450,241	50,155,783	6,294,458	2,852,191
1890	77,266,989	62,947,714	14,319,275	5,246,613
1900	100,355,985	75,994,575	24,361,410	3,687,564

We have here to consider two phenomena occurring during the same period of time: a relative decline of the native stock, produced by a lowering of the birthrate; and a large infusion of the foreign element, through immigration. General Walker, after comparing Watson's estimates with the census returns, and considering the flow of immigration, came to the conclusion that immigration was the cause and the relative decline of the native population was the effect; that Watson's estimates would have proved correct if immigration had not occurred. "The access of foreigners," he wrote, "at the time and under the conditions, constituted a shock to the principle of population among the native element. That principle is always acutely sensitive alike to sentimental and to economic conditions. And it is to be noted, in passing, that not only did the decline in the native element, as a whole, take place in singular correspondence with the excess of foreign arrivals, but it occurred chiefly in just those regions to which the newcomers most freely resorted."

He believed that the incoming of the foreigner operated in two ways to check the disposition of the native toward the increase of population at the "traditional" rate. The first reason is sentimental:

Throughout the northeastern and northern middle states, into which, during the period under consideration, the newcomers poured in such numbers, the standard of material living, of general intelligence, of social decency, had been singularly high. Life, even at its hardest, had always had its luxuries; the babe had been a thing of beauty, to be delicately nurtured and proudly exhibited; the growing child had been decently dressed, at least for school and church; the house had been kept in order, at whatever cost, the gate hung, the shutters in place, while the front yard had been made to bloom with simple flowers; the village church, the public schoolhouse, had been the best which the community, with great exertions and sacrifice, could erect and maintain.

Then came the foreigner, making his way into the little village, bringing —small blame to him!—not only a vastly lower standard of living, but too often an actual present incapacity even to understand the refinements of

life and thought in the community in which he sought a home. Our people had to look upon houses that were mere shells for human habitations, the gate unhung, the shutters flapping or falling, green pools in the yard, babes and young children rolling about half naked or worse, neglected, dirty, unkempt. Was there not, in this, sentimental reason strong enough to give a shock to the principle of population?

But there was, besides, an economic reason for the check to the native increase. The American shrank from the industrial competition thus thrust upon him. He was unwilling himself to engage in the lowest kind of day labor with these new elements of the population; he was even more unwilling to bring sons and daughters into the world to enter into that competition. For the first time in our history the people of the free states became divided into classes. Those classes were natives and foreigners. Politically the distinction had only a certain force, which yielded more or less readily under partisan pressure, but socially and industrially that distinction has been a tremendous power, and its chief effects have been wrought upon population. Neither the social companionship nor the industrial competition of the foreigner has, broadly speaking, been welcome to the native. * * * *

If the foregoing views are true, or contain any considerable degree of truth, foreign immigration into this country has, from the time it first assumed large proportions, amounted not to a re-enforcement of our population, but to a replacement of native by foreign stock. That if the foreigners had not come, the native element would long have filled the places the foreigners usurped, I entertain not a doubt. The competency of the American stock to do this it would be absurd to question in the face of such a record as that for 1790 to 1830.

According, then, to the view of General Walker and of the many who have followed him, the native Americans, to protect their standard of living in the competition with immigrants of lower standards, have limited the number of their offspring. It is further claimed that if this lowered rate of increase of the native element had not taken place, our population from native stock alone would have been fully as large as it is now; that, in fact, "for every immigrant who lands in America one less child is born to an American," so that the coming of immigrants when viewed over a long period of time is but a substitution of one race for another.

There is no argument about the fact of the declining birthrate. The census reports show a declining rate of increase of the total population, which has occurred despite the arrival of many million immigrants.

PERCENTAGE INCREASE OF POPULATION OVER PRECEDING CENSUS

1790		1860	35.6
1800	35.1	1870	26.6
1810	35.4	1880	26.0
1820	33.1	1890	24.9
1830	33.5	1900	20.7
1840	32.7	1910	21.0
1850	35.9	1920	14.9

Population showed an increase of approximately one third during each of the seven decades from 1790 to 1860, of one fourth during each of the three decades from 1860 to 1890, of one fifth during each of the two decades from 1890 to 1910, and of one seventh during the last decade.

Since this declining rate of increase has occurred at the same time that the death rate has been declining, and since no appreciable movement of population away from the country has taken place, it argues that the birthrate has fallen off. But that the declining birthrate has been caused by immigration is a matter on which judgment should be suspended until all the facts have been investigated. We must be careful to avoid the common fallacy of generalization known as *post hoc, ergo propter hoc*—a conclusion that because one event takes place after another, it occurs on that account; as, for example, to argue that because night follows day, it follows as a result or consequence of day. This type of fallacious reasoning is usually committed in attempting to explain complicated phenomena by a simpler theory than their nature admits of. There may be strong evidence that the decline in the native birthrate would have occurred anyway, even if there had been no immigration. The growth of immigration and the decline of the native birthrate, instead of being cause and effect, may conceivably be two different effects of the same cause, *viz.*, the industrial development and urbanization of the continent.

The original assumption in the process of reasoning which I am criticizing was made by Elkanah Watson when he assumed that population, immigration or no immigration, would continue to increase in the same ratio. Had he known anything about the law of population, he would not have made such a rash prediction.

The law governing the growth of population is that numbers tend to increase up to the limit of the supporting power of the environment (land), on a given stage of the arts, and for a given standard of living. It is this ratio of population to land that determines the basic conditions of life. If the amount of land is relatively large or is increased, or if the level of the arts of life is raised, population may increase accordingly. The standard of living affects numbers in the opposite way: if the standard is raised, numbers tend to fall off; if lowered, numbers increase.

The early Americans had a lower standard of living than that which now prevails; the stage of the arts was lower, too, but the amount of land relatively to numbers was extraordinarily high. The conjuncture was overwhelmingly in favor of men as against land. Hence the rapid increase of population that was characteristic of our early days. On the frontier where land is plenty and

men scarce, the unoccupied land constitutes a sort of vacuum into which population tends to flow, not only by immigration, but also by natural increase. At the time when Watson wrote, these were the conditions. This was a new and largely unsettled country, the people were engaged mainly in agriculture, there were almost no large cities, and consequently the birthrate was unusually high. Such is always the result in new countries and under pioneer conditions. Marriage takes place early, and children, under the existing conditions of easy support, brief education, scarcity of labor, and the like, are economic assets, where, in a more developed society, they are liabilities. All colonies and new countries in the temperate zone have shown this capacity for rapid growth.

When, later, the country has been brought under the control of man, it naturally follows that the rate of increase, under the new conditions of greater density of population, will decline. No old and densely settled country ever shows as rapid an increase of population as does a new country, and as a new country approaches old-world conditions its rate of increase gradually falls off. The early rate of increase could not be maintained forever unchanged, for as fast as the land is taken up there results a limitation to rate of growth of population. The vacuum ceases to be a vacuum and there is a check on expansion. If the early rate of increase should continue unchanged, it would not take many decades to produce a condition in which there would be more people than the country could possibly support on any acceptable standard of living. It is as absurd to predict the continuance of the same rate of increase of population as to predict that the rate of growth of railroads would continue unchanged. When we began to build railroads about 1830 there was obviously much room for expansion, and as a result the amount of new mileage increased rapidly. There was a period of great extension culminating in 1890 (the year, be it noted, when our frontier was first said to have disappeared); since then the rate of growth has slackened and now new construction has almost ceased. This is exactly what one would expect. So it is hard to escape the conclusion, in regard to population, that the rate of increase would have declined irrespective of immigration. The large family of early days continued just as long as early conditions continued and no longer.

One does not need to resort to a theory that native Americans refused to bring children into the world to compete in the labor market with immigrants, in order to explain the phenomenon of the declining birthrate. There are plenty of other causative factors bearing on that occurrence, most of which are attributable to the changed conditions which have come over the United States.

Our falling birthrate correlates directly with the industrial and social changes of the past half century. We used to be a nation of farmers; we are now a great manufacturing and commercial nation. The majority of Americans once lived in rural communities; now over half of the people live in cities. We used to have great unsettled tracts of land; now we have none. Our density of population was formerly insignificant (4.5 people to the square mile in 1790); while it is still small in comparison with most European countries, it has been increased by many times (35.5 in 1920). All this means a growth of industrialism and of urbanization, and it will be found to explain fully enough the phenomenon of a declining birthrate. In terms of the law of population, it means a less favorable conjuncture of men as against land and also, as will be seen, a rising standard of living.

Let us look a little farther into these modern conditions and observe their effects. Children on the farms are an asset, in cities they are a liability. Children in the country find more work fitted to their strength and are of greater assistance to the family than in the city. Furthermore, the raising of the age for leaving school and allied changes as to work, which apply principally to cities—observe our child labor laws—are preventing children from being an early source of profit. As a result, families in the country are larger than families in the city, and since the proportion of urban population is increasing, the rate of growth of the total population is decreasing. City conditions do not favor a rapid natural increase. The characteristic mode of city growth is by accretion.

There is a marked tendency for a greater proportion of the population to remain permanently single, and for those who marry to postpone matrimony to a later age. This is particularly true of cities, where the expense of housekeeping and child-rearing obliges many to defer marriage. In the country districts single life has not so many resources, such as clubs and amusements; it is more of a bore, and so man is thrown back on domestic life. Besides, a wife is of economic utility. The emancipation of women seems to have proceeded farther in urban communities, and one result of their changed industrial and social status is the tendency to bear fewer children.

The necessity for more expensive training, to fit children to take part in the mental and industrial life of the nation, is also operating as a check on increase of numbers. There appears to be a more vivid realization of the responsibility of parenthood, and higher ambition on the part of parents for their children. As a consequence, parents are perceiving that to give their children advantages they must have fewer children.

The growing burdensomeness of large families and the high cost of living, together with a greater desire for luxury and a general raising of the standard of comfort, have further combined to restrict numbers. There has also occurred a gradual slackening of religious restraints, especially noticeable in cities. But greater than these special causes is the deliberate and voluntary avoidance of child-bearing on the part of a steadily increasing number of married people, who not only prefer to have but few children, but who know how to realize their preference. The desire to improve their social position acts so powerfully upon many families that they are willing to sacrifice anything to obtain this end. These are the considerations that consciously or unconsciously affect the average American, and they, rather than the fear of competition with immigrants, account for the dwindling birthrate.

Observe now the correlation between this explanation of the declining birthrate and the flow of immigration. It is the industrial development and urbanization of the country that has furnished the demand for immigrants, chiefly for unskilled industrial laborers, and as that development has progressed the demand for immigrant workers has increased. This development further explains the fact that the native birthrate has declined most noticeably in those sections of the United States to which immigrants have chiefly gone. The native birthrate appears to be lowest in the most industrialized and urbanized parts of the country, and it is because of those very conditions. And the immigrants are concentrated in those sections for the reason that there the demand for such workers is greatest. If immigration has at all affected the native birthrate, it has done so indirectly by furthering our industrial advancement. So the rapid development of industry, and with it the growth of cities—in a word, the changed type of society in America—is a fundamental cause of both the increasing flow of immigration and the declining birthrate.

At this point it is pertinent to ask which is the real cause of the declining birthrate—competition with immigrants or these changed conditions? If one should still believe that immigration has caused the native stock relatively to decline, what will he say about the following facts? The decreasing birthrate is not solely an American characteristic, but has been a common phenomenon in almost all European countries during the last fifty years or so, and particularly during the latter part of the nineteenth century. Now, if competition with immigrants of lower standard of living has produced the decline in rate of increase of our American stock, how can one explain, on that basis, the fact that the birthrate has declined in other countries where there is no competition with

immigrants at all, but from which the immigrants have come? The real reasons for that decline are the same as the reasons for the decline in America: industrialization and urbanization.

Furthermore, Australia, where the immigration has been slight, and akin to the native population in blood, is lamenting her declining birthrate. In 1902 a commission was appointed by the New South Wales Government to inquire into the causes of the declining birthrate in that country. Its reports stated that in the last thirty years Australia had lost a natural addition of twenty-five thousand. The decrease was to a large extent artificially created, many witnesses admitting deliberate restriction of family. The population of Australia as a whole is not dense, but the proportion of city-dwellers is very high and the birthrate is low and declining without the influence of immigration.

Let me state, further, that the falling birthrate in this country is most marked among the classes who are not in competition with the immigrants. It is a matter of common knowledge that the birthrate seems to vary inversely with the amount of income. The highest birthrate is found among the classes in the lowest income-groups. With these there is thoughtlessness for what the morrow may bring. The alarming reports about the declining birthrate refer mainly to the so-called upper classes. Cattell finds that the average Harvard graduate is the father of three fourths of a son and the average Vassar graduate the mother of one half of a daughter; and that the average family of American men of science is only 2.22 as compared with an average of 4.66 for the country. To increase our worry about these fractional children, Popenoe and Johnson give similar results summarizing many statistical studies of Yale, Harvard and other educational institutions. Surely no one will say that these classes are restricting the number of their offspring on account of competition with low-standard immigrants or because of any "sentimental" reason arising from dislike of the way in which immigrants live.

Moreover, if one will observe the immigrants themselves he will note the same tendency, as time goes on, to have fewer children. The foreign-born have the highest birthrate; the second generation, that is, the native-born of foreign parents, have a lower rate; while the next generation, the native-born of native parentage, have a still lower birthrate. Is competition, which in this case would have to be with themselves or with other immigrants, the explanation, or is this decline among the foreign stock due rather to their increasing prosperity, to their advancing standard of living?

The conclusion is inevitable that Walker's explanation of the declining native birthrate is incorrect. The lessening birthrate

itself, however, is a matter of great significance, to which the attention of the public should be directed. The native population in some sections is barely holding its own, in others it is actually dying out with considerable rapidity. On the other hand, the immigrants and, in turn, their children, are reproducing at a higher rate than the native-born of native parentage. This situation—a differential birthrate—may produce real race suicide, in the sense in which the term was originally used by its inventor, Professor E. A. Ross. That is to say, the native stock may so decline, relatively, that the foreign element will become greater than it in numbers, owing simply to differences in the rate of increase. Dr. Louis I. Dublin has pointed out the real significance of the declining birthrate among the native stock, where two or three children seem to be the rule. In order, he says, for our native stock to maintain itself, without increase or decrease, it is necessary that every married couple have at least four children, for not every person lives to a reproductive age, many people do not marry, and there is a considerable proportion of unions which are sterile. Yet there is much evidence that the best blood of America is being thinned out by the exercise of a conscious limitation of births. If the native stock deliberately and increasingly limits its own increase in this way, and if at the same time the foreign stock exercises a much lesser check on increase of numbers, in time the obvious result of this differential birthrate will be to change the character of the predominant racial type in America. This effect is to be noted without any reference to the comparative worth of one stock as against another. It is not a question as to whether the basic stock in this country is superior or inferior. It is simply a question as to whether, in its own interest, it is to be perpetuated. If America is to remain a nation of predominantly the same stock that it has been in the past, or is now, the admission of more rapidly increasing stocks must be stopped.

Here we find a reason for the restriction of immigration, based not on a supposition that immigration causes a replacement of native by foreign stock, but on a differential birthrate due to differences in standards of living. Since, therefore, we have a reason for restriction which is valid, why should we base our argument on unsound theory like Walker's?

THE DEVELOPMENT OF GEOLOGIC SCIENCE

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The Beginnings of Earth Science

We have slight record of any nature study by the ancient oriental peoples. The old cosmogonies of Chaldea and Assyria, borrowed by the Hebrews, illustrate the psychologic phenomenon of the tendency to search for the remote and the unseen to the neglect of the near and the common.

The active-minded Greeks made an excellent beginning in geology, being free from religious bigotry and not required to shape their thinking to a fanciful and false cosmogony. Their great philosophers during five centuries B. C were truly scientific, and the science of that time was equal to that of Christianized Europe in the fifteenth century. Some examples are pertinent. Pythagoras, about 500 years B. C., recognized geologic processes and agencies. Herodotus, over 400 B. C., knew fossils to be remains of once living organisms. And Aristotle, over three centuries B. C., grasped the fundamental conception of evolution. The great school at Alexandria, founded about 275 B. C., with its research laboratories in physical sciences, gave serious attention to geography. Following the Greeks a few Romans continued the nature study. Strabo, about 20 B. C., records in 17 volumes his acute observations and shows a broad knowledge of geologic changes. Seneca, 2–65 A. D., described the work of rivers in erosion and deposition, and of sedimentation in the sea; while the elder Pliny was author of 37 volumes in natural history. But "... the flicker that Pliny kindled upon the dying embers of Greek learning was allowed to go entirely out."

With the disordered state of the western world, following the ruin of Greek and Roman civilization, the study of nature was forgotten; and for a thousand years it was not only neglected but despised, for early Christianity held the material world to be accursed and expected its quick destruction. Down to the fourteenth century the Arabians were the only people with scientific interest, mainly in physical and chemical study, and in mineralogy. Omar Khayyam, who died about 1123, was somewhat a geologist, but his views were discordant with the Koran; his recantation was demanded, and he went into exile.

In the fifteenth century science shared in the renaissance. The revival of learning brought to light some of the scientific knowledge and conceptions of the free thought of pre-Christian time; the Protestant reformation gave an impulse to research and self-expression; while the discovery of the Americas aroused interest in geography. But, most unfortunately for intellectual progress, Christianity had included in its "sacred writings" the folk-lore and fanciful Mosaic cosmogony of the Hebrews, and invested them with supernatural authority. Discoveries in science were bound to contravene the literal interpretation of such "holy scriptures."

The most unhappy chapter in the intellectual history of the world is that of the persecution of men of science by religious bigotry and intolerance of the Christian church. And Protestants were scarcely less guilty than the Jesuits, although their shibboleth was freedom.[1] And we may not forget that we yet have with us the same ignorant, conceited, bigoted intolerance, but under restraint. Many millions of people in America to-day, in this supposedly intelligent age, regard Genesis as of divine revelation with literal interpretation of its legendary narratives. And most of them think that the Lord dictated it to Moses in the English language.

The pitiful story of the struggle of geology against superstition can not be told here, but a few steps in the progress may be noted. It was not until the middle of the eighteenth century that scientific men in general accepted so evident a fact as the organic origin of fossils. The many absurd explanations would be amusing if they were not so pitiful. It took Europeans over 2,000 years to recover the reasonable mental attitude of Herodotus and Aristotle. And when the organic origin of fossils was finally admitted, another obstruction was laid in the path of mental progress—the fossils were relics and proof of the Noachan deluge; and the battle with religious superstition had to be fought another century.

Leonardo da Vinci (1452–1519) was not only a great engineer and artist, but was one of the founders of modern geology. Another was George Bauer (Agricola) (1494–1555), who has been called the father of mineralogy and metallurgy.

Giordano Bruno was so far ahead of his time in his conception of nature, and so brave in his utterance, that he was burned at Rome in 1600. We honor him as a martyr to science.

The earliest comprehensive writing about the earth was by Kircher (1602–1680). Nikolas Steno, a Dane (1638–1687), recognized the principles of stratigraphy and the fact of deformation of strata into folds and mountains. Archibald Geikie gives great

[1] The shameful story is told in Andrew D. White's "Warfare of Science."

credit to Jean Etienne Guettard (1715–1786), whose voluminous writings were freely used, but with insufficient credit. The first writer to frame a comprehensive account of the earth's history was Buffon, in 1749, for which he was forced by the church to make abject recantation. The great Leibnitz (1744–1829) tried to harmonize Genesis with geology. The religious school of geology in England was represented by John Woodward (1665–1722), who is one of the geologists buried in Westminster Abbey.

The irrational conceit of scholastic theology is illustrated in the writings and sermons of the great and good John Wesley (1703–1791), who taught that before sin entered the world there were no volcanoes nor earthquakes. Earthquakes were the "effect of that curse which was brought upon the earth by the original transgression." Wesley had a sermon on the "Cause and Cure of Earthquakes," which is not listed in our geologic bibliography. Down to about the middle of the nineteenth century, or until Lyell shamed them, it appears that the chief pastime of some theologians was to ridicule geology and to abuse its devotees. Now biology and evolution have relieved geology.

Geology in England

England was always in the front line of geologic progress, and a long list of honored names could be given. Mention must be made of a group of eminent men in the closing years of the eighteenth and first part of the nineteenth centuries. Dr. James Hutton (1726–1797) is regarded as the founder of dynamical geology. Sir James Hall (1762–1831) was the founder of experimental geology. William Smith (1769–1839) was the father of English stratigraphic and historical geology, and of geologic cartography. Roderick I. Murchison (1792–1871) and Adam Sedgwick (1785–1873) described the older strata and applied the names Cambrian, Silurian and Devonian, now in use over the world. The Geological Society of London was founded in 1807.

While these men and others, English and European, contributed largely to the knowledge of the globe it remained for Charles Lyell (1797–1875) to collect the mass of fact and place it before the world in convincing manner. Like his friends and coworkers, von Buch and Humboldt, he had the wealth which enabled him to devote his life to science. He exemplified the saying that the first, second and third requisites of a geologist is travel, visiting America three times. The first volume of his "Principles of Geology" appeared in 1830. Its immediate popularity was shown by the expansion of the third edition, in 1834, into four volumes. By 1875 it had run to twelve editions. The volume 4 (1834), treating historical geology, was

recast in 1838 as the "Elements of Geology," which had six editions by 1871.

Down to Lyell's time the doctrine of cataclysms or catastrophes was commonly held, perhaps chiefly for the reason that it helped to explain the Genesis cosmogony and the story of the deluge. Lyell was the vigorous opponent of catastrophism and he established the doctrine of uniformity. He proved, even for the theologians, that the earth's features are wholly the product of forces and agents now working, and that the past must be interpreted in terms of the present. He marshalled the then-existing knowledge to prove that geologic processes are continuous, and that the present forces, as a whole, are as effective as in the past. While Lyell's uniformitarianism was somewhat extreme, as a reaction from catastrophism, allowing neither beginning nor end to nature's activities, it was essentially true, finding no place for a "flood" or any other supernatural interferences in the material world.

Lyell's teaching found such general acceptance that the way was cleared for the extension of the doctrine of evolution to the organic world. Before Darwin was Lyell. At the age of 62, when many strong men find it difficult to accept new views, Lyell cordially adopted the theory of Darwin, his pupil and friend, and for the tenth edition of his "Principles" completely rewrote the chapters on the distribution of life, accepting the theory of descent by natural selection. Agassiz, only two years his senior, opposed "Darwinism" to the end of his life.

Darwin was a geologist, but his fame in biology has obscured his influence in geology. He made important contributions to stratigraphic and historical geology, especially by emphasizing the enormous length of time and the fragmentary character of the geologic record.

Geology in America before 1848[2]

Status in Education

During all colonial time, and in the period of stress following the Revolution, little attention was given to science of any kind. Down to the second decade of the century the colleges taught almost no science except medicine. And it is an interesting fact that down to about 1870 a large proportion of American geologists were physicians, for the reason that they were the only men with any training that could be called scientific.

[2] The year 1848 is here used as a convenient and critical date of reference, lying near the middle of the nineteenth century, and marking an era in American science through the organization of the American Association for the Advancement of Science.

The first professional position in science was in 1802, when Benjamin Silliman was made professor of chemistry at Yale. The inferior standing of science is shown by the fact that Silliman was then only a law student, 22 years of age, and with no knowledge of the subject he was called to teach. With some preparation he gave his first lecture in 1804, and his subsequent service to science, including geology, justified his selection. During 50 years he was the dominating personal influence, especially through his *American Journal of Science,* founded in 1818.

It is difficult to say when the first chair of geology was established, because the subject was so long included under the omnibus term "Natural History." We know that Amos Eaton lectured at Williams in 1916, and was professor of sciences at the Rensselaer School in 1824. By 1848 several leading colleges had included geology in their courses. In 1850 James D. Dana was professor of natural history at Yale, and not until 1864 was his chair made geology and mineralogy. The giants in geology of those early years were mostly self-taught.

Until 1840 American students looked to Europe, especially to England, for geologic literature and standards. In later years this deference was a detriment to our stratigraphic study and nomenclature.[3] As late as 1837 Edward Hitchcock republished De la Beche's "Researches in Theoretic Geology," a small octavo with no illustrations. The early American books in geology are pitiful in both matter and illustrations.[4] The first important text-book was "Elementary Geology," by Edward Hitchcock, in 1841, which was in America what Lyell's work was in England. By 1860 it had run to 30 editions. The first book to make large use of illustrations was Ebenezer Emmons's "Manual of Geology," 1855. In 1863 all previous text-books were superseded by Dana's "Manual of Geology," which was for 40 years the American geologist's hand-book.

Journals and Societies

The first periodical intended for mineralogists and geologists was the *American Mineralogical Journal,* which endured only four years, 1810–1814. The *American Journal of Science* began in 1818 and retained preeminence as the medium for geologic literature to 1888.

In 1819 the American Geological Society was organized at Yale, with William Maclure as president. This was the earliest society devoted to geologic science, but it survived only to 1828, and published nothing.

[3] See Dr. John M. Clarke's "Life of James Hall," Albany, 1921.

[4] *Science,* Vol. 54, 1921, p. 494.

The Association of American Geologists, organized at Philadelphia, April 2, 1840, was the first permanent society in America, of national scope, devoted mainly to earth-science. This society had its beginning in the Board of Geologists of the New York Geological Survey. Eighteen men participated in the organization. In 1843 the association widened its scope and became the Association of American Geologists and Naturalists. The proceedings of the meetings were published in the *American Journal of Science,* and a volume of 544 pages and 21 plates covering the three meetings of the original society was published in 1843.

In 1847 the society decided to include other branches of science, and the first constitution of the American Association for the Advancement of Science was drafted by H. D. Rogers, Benjamin Peirce and Louis Agassiz, following closely the constitution of the British association. The formal organization occurred at Philadelphia, September 21, 1848, with William C. Redfield as president.

Previous to 1848 the geologic literature was either in the *American Journal of Science* or in the transactions of the following scientific societies: American Philosophical Society, Philadelphia, founded 1769; American Academy of Arts and Sciences, Boston, founded 1780; Academy of Natural Sciences, Philadelphia, founded 1812; Lyceum of Natural History (since 1876 New York Academy of Sciences) founded 1817; Boston Society of Natural History, founded 1830.

Research and Personal Publication

The earliest articles on American earth-science were in mineralogy. The first paper on American geology was published in German, in Germany, by Schöpf in 1787.

Our first paleontologist was Thomas Jefferson, who pursued his study of vertebrate fossils during the years of his active political service, publishing a paper in the Transactions of the American Philosophical Society in 1797.

Not until 1809 did America produce a geologic paper of note. In that year William Maclure, a naturalized Englishman, published as the result of years of intensive field-study and travel over the territory east of the Mississippi, mostly uncharted and in wilderness, his "Observations on the Geology of the United States," including a geologic map. He has been called the father of American geology. This honorable title might be claimed for Amos Eaton, who published in 1818, for the use of classes in Williams College, his "Index to the Geology of the Northern States," which was the first attempt at an orderly succession of the rock strata. In 1830 he published his Geological Text-Book, with colored map.

The earliest geologic "surveys" were also made by Eaton, in New York, of the Helderbergs and Catskills in 1819, and of the "Vicinity of the Erie Canal" in 1823–1824; both being financed by Stephen Van Renssalacr.

With the beginning of official state surveys, about 1830, the necessity for study and publication at personal expense was largely passed.

Official Surveys

This topic has been very interestingly covered by George P. Merrill in chapters III and IV of his "Contributions to the History of American Geology." He states that, by 1849, 20 states had established surveys.

The first survey completed at state expense was that of Massachusetts, in 1830–1833, by Edward Hitchcock. The Rogers survey of Pennsylvania and the epoch-making survey of New York began in 1836. The Canadian survey was established in 1841, and William E. Logan made director in 1842.

The most influential of all the geologic reports was that of James Hall on the "Fourth District" of New York, published in 1843, which established the stratigraphic succession, and its nomenclature, for American Silurian and Devonian.

American geologists before 1848

William Maclure, 1763–1840
Samuel L. Mitchill, 1764–1831
Amos Eaton, 1776–1842
Gerard Troost, 1776–1850
Benjamin Silliman, 1779–1864
Chester Dewey, 1784–1867
Lardner Vanuxem, 1792–1848
Edward Hitchcock, 1793–1864
Ebenezer Emmons, 1799–1863
Timothy A. Conrad, 1803–1877
William W. Mather, 1804–1859
William B. Rogers, 1804–1882
Michael Toumey, 1805–1857
Charles T. Jackson, 1805–1880
David Dale Owen, 1807–1860
Henry D. Rogers, 1808–1866
Charles Whittlesey, 1808–1886
Douglas Houghton, 1809–1845
Oliver P. Hubbard, 1809–1900
Richard Owen, 1810–1890
Increase A. Lapham, 1811–1870
James Hall, 1811–1898
James D. Dana, 1813–1895
Bela Hubbard, 1814–1896

Events and Forces

Publication, in 1809, of Maclure's article, "Observations on the geology of the United States."

The personal influence of Benjamin Silliman (1779–1864), who began teaching in 1804, and founded the *American Journal of Science* in 1818.

The work of Amos Eaton (1776–1842), the early teacher and leader in geology as a separate science.

The organization of the Association of American Geologists in 1840.

Charles Lyell's visits to America, in 1841, 1845, 1852.

The introduction of glacial geology, in 1841.

Emmons's discovery of the Taconic (Cambrian) system, 1841–1842.

The publication of James Hall's Report on the Fourth New York District, in 1843, and three other New York reports.

Description of the structure of the Appalachians by the Roger brothers, in 1842.

The arrival of Louis Agassiz, in 1846.

Publication of the first volume of James Hall's series in paleontology, in 1847.

Footprints in the Connecticut Valley Brownstone

In 1848 the geologists were discussing one of the most interesting discoveries in America. The footprints in the red shales and sandstone of the Connecticut Valley were first called to public attention by Edward Hitchcock, in 1836, who, during later years, made the great collection at Amherst. He diagnosed the three-toed tracks as those of birds, in which opinion the great authorities of Europe concurred. In 1845 Hitchcock had 49 species, 32 of which he regarded as avian. His classic description is the "Ichnology of New England," published in 1858.

In 1860 Mr. Roswell Field claimed that all the tracks were reptilian;[5] and in 1893 the skeleton was found of a dinosaur with the birdlike hind feet.

As the dinosaurs have avian characters, and the archeopteryx is quite as much reptile as bird, it may yet be possible that some of the smaller tracks were made by animals more bird than reptile.

The Taconic Dispute

During the middle of the century the long and bitter conflict over the Taconic question was active. This matter illustrates the difficulties and the progress in stratigraphic geology, and in its nomenclature.

As early as 1841 Ebenezer Emmons announced that he had found strata and fossils in eastern New York and western Massachusetts which were stratigraphically lower, and therefore older, than the Silurian as then recognized. For the new system he proposed the name "Taconic," from the hills of that name in the southern Berkshires. Naturally, such a discovery excited great interest, and many geologists, including the Canadians, studied the area through many years, and with diverse conclusions. The strata were so disturbed, overturned and metamorphosed that the problem was a topic of acrid debate for 60 years.[6] Emmons was treated ungenerously, and wearied and embittered he went to the North Carolina Survey in 1851 and died there during the civil war.

[5] Paper in the *Amer. Jour. of Science,* Vol. 29. The full history of this matter is given by Dr. G. P. Merrill in his Contributions.

[6] A detailed and interesting account of this unhappy episode in American geology is given by Dr. Merrill.

Like all the workers Emmons made errors in his diagnosis of the rocks and of their original position, but his fundamental postulate was correct, and we now recognize his old pre-Silurian system, although under a different name. During the discussion in America a somewhat similar one arose in England, between Murchison and Sedgwick. The latter claimed to have found strata in Wales older than the lowest of the recognized Silurian, and for which he proposed the name Cambrian, from the old Latin name for Wales. And he wished to include in his Cambrian the lower beds of Murchison's Silurian.

Contemporary with this study the great paleontologist, Joachim Barrande (1799–1883), a Frenchman living in Bohemia, discovered a remarkable assemblage of fossils, especially Trilobites, which antedated the organisms of the Silurian; and for this new geologic system he proposed the name Primordial.

Here was a discovery of prime importance in historical geology, made by three men working independently in far-separated lands, at nearly the same time. Priority belonged to Emmons's Taconic. But the American strata were so complicated by disturbances subsequent to their deposition that Emmons, hampered by criticism and jealousy instead of being assisted, was not able properly to limit and characterize the system. While the discussion was on, and with too great deference to British authority and terminology, Sedgwick's name Cambrian came to be used, and has been generally accepted. Similarly, the name Ordovician, another Celtic name, has displaced Lower Silurian; while Silurian is Celtic and Devonian is English. Thus all our period names for the Paleozoic up to the old Carboniferous are borrowed. In the forties James Hall proposed appropriate names drawn from the type areas in New York, which might have been used in America instead of foreign names.

Status in 1848

Up to this time American geology was mainly description and correlation of rock strata and of the contained fossils. The value of the fossils in proving the time-relation of the rocks was fully recognized after the publication of Hall's first volume of paleontology. The students of the science were too busy with the new and captivating stratigraphic features of eastern America to give much thought to theoretic or philosophic problems. They were intent on discovery and description. By 1848 the stratigraphic sequence of the eastern border of the continent was fairly established. The wonderful geology of the far west waited until after the civil war.

The many state surveys were employing the men who were not in college work, but altogether they were few. Of the 461 members

of the American Association for the Advancement of Science listed in the first volume of its proceedings only about 18 names are recognized as those of working geologists; ten of these having been in the parent association (including Vanuxem and Houghton, deceased). And five of the latter were on the New York Survey. This was the day of primitive conditions compared with the present. The latest printed list of the Geological Society of America (1922) includes 477 living fellows, mostly professional geologists, and 123 deceased fellows. And numbers of younger men, and a great number in economic work (especially oil geology) are not yet in the G. S. A.

During the early years a few important dynamical subjects were introduced. The chemical interaction of the atmosphere and the earth's crust were recognized by Vanuxem in 1827; and in 1844 H. D. Rogers made estimate of the storage in the rocks of carbon taken from the air. The yet-active topic of metamorphism was introduced by Dana in 1843, and in 1847 he began the study of a subject yet under discussion—the effects of shrinkage of the globe, the production of mountains and the origin of continents. Amos Binney in 1846 introduced the problem of the loess.

Catastrophism was passing out, and although deference was yet paid to Genesis the continuity and competency of ordinary geologic processes were fairly accepted. The last phase of the cataclysmic idea related to the "drift." Beside the Taconic dispute and the puzzle of the footprints in the sands of Mesozoic time there had been from about 1830 a very animated discussion over the origin of the deposits which we know as glacial. The sheet of rock-rubbish, the moraines, drumlins and eskers, so prominent in New England and New York, were such singular and abnormal features as to be unexplainable by any agencies then known. The geologists were pardonable for invoking tremendous débâcles of water from the north. This fanciful and wild conception had much vogue, but had been jolted by Agassiz's discoveries relating to land ice, which Hitchcock had presented in 1841. The arrival of Agassiz in 1846 gave reinforcement to the glacialists, but the diluvialists were not entirely subdued for some years.[7]

The geologists of 1848 doubtless were proud of their science and of their success in probing the earth. And they were justified. But as we look back on that time their field of geology appears so narrow as compared with the present highly differentiated and complex science; and we note the small area which they had covered, and the little company of workers as compared to the present well-organized army.

[7] See the Proceedings of Amer. Assoc. Adv. Sci., Vol. 47, 1898, pp. 257–290; also *Amer. Geologist*, Vol. 22, 1898, pp. 154–189.

Geology Since 1848

Preliminary Outline

A period of suspense in all scientific work was due to the civil war with the years of stress immediately before and after, 1856–1866.

Previous to the civil war geologic exploration was confined chiefly to territory east of the Mississippi, while since that time the far west has been the field of great discovery. Merrill calls the long period from 1830 to 1870 that of "State Surveys."

Following are some of the more important events in the progress of geology before 1900:

James Hall's series of 15 volumes in paleontology, 1847–1898.
J. D. Whitney's "Metallic Wealth of the United States," 1854.
Permian strata found in Kansas, 1858; in Pennsylvania (published), 1880.
J. W. Dawson's "Acadian Geology," 1855 (3rd edition, 1878).
Pacific Railroad reports, 13 volumes, 1855–1860.
Edward Hitchcock's article on "Surface Geology," 1856.
H. D. Rogers's "Geology of Pennsylvania," two volumes, 1858.
J. S. Newberry's report on the Ives exploration of the lower Colorado Valley, 1859.
Dana's "Manual of Geology," first edition, 1863.
W. E. Logan's "Geology of Canada," 1863.
Discussion of the nature of "Eozoon," 1865–1894.
F. V. Hayden's surveys of the Rocky Mountain region, 1867–1879. (His personal work began in 1853.)
Clarence King's survey of the 40th parallel, 1867–1877.
G. M. Wheeler surveys, 1869–1879.
Joseph LeConte's papers on geophysical problems, 1872–1896.
Discussion of the "Laramie problem," age of the lignites, 1872–1897.
Second geological survey of Pennsylvania (Lesley's), 1874–1887.
J. W. Powell's "Exploration of the Colorado River," 1875, and "Geology of the Uinta Mountains," 1876.
G. K. Gilbert's report on the geology of the Henry Mountains, 1880. (The subject of "Laccolites" noted by Peale in 1875, and taken up by Gilbert in 1877), and his report on Lake Bonneville, 1877–1890.
Establishment of the United States Geological Survey, 1879.
C. E. Dutton's report on the high plateaus of Utah, 1880.
W. P. Jenney and Henry Newton's report on the Black Hills of Dakota, 1880.
Geological Society of America, organized, December, 1888; its Bulletin begun, February, 1890.
N. H. Darton's catalogue and index of contributions to North American geology, 1732–1891. (U. S. Geol. Surv. Bulletin 127), 1896.

Differentiation; Organizations

As in all departments of knowledge geology, with its expansion, has become specialized, and this produces division and multiplication of societies. The American Association was never able ade-

quately to publish and illustrate its geologic papers, and with the interest and growth in geology attending the development of a great continent the geologists organized in 1888 a new, professional society. Accredited Fellows of Section E were eligible as original members of the Geological Society of America, which has become the leading society of the world devoted to geology.

The Geological Society of America has in turn several offshoots: the Association of American Geographers, organized in 1904; the Paleontological Society, 1909; the Mineralogical Society of America, 1920; and the Society of Economic Geologists, in 1920. A branch of the Geological Society, the Cordilleran Section, organized in 1899, has as its province the western part of the continent. The Seismological Society was organized in 1910.

Two other geological societies now exist, the Southwestern Geological Society, with headquarters in Texas; and the American Association of Petroleum Geologists, having a very large membership.

Publication; Literature

From about 1835 until 1888 the state surveys furnished a medium for most of the areal and descriptive literature. In January, 1888, the first distinctively geologic periodical was launched by a small group of men led by N. H. Winchell. This *American Geologist* was carried through 36 annual volumes, to 1895, when it was merged with the new journal, *Economic Geology.*

In February, 1890, the Geological Society issued the first brochure of Volume 1 of its bulletin, with 33 annual volumes now complete, and three volumes of indexes.

In 1893 the *Journal of Geology* was founded by the department of geology of the University of Chicago. *Economic Geology,* as noted above, was begun in 1905.

To-day we have as geologic literature not only the above named journals but the voluminous reports of the many active state surveys, and especially the several series of splendid publications by the United States Geological Survey. The geographical societies and their several journals must also be included in the broad field of study in earth-science.

Exploration; Official Surveys

The decade following 1848 was a time of activity in geologic surveys by the states, and the stratigraphy in the territory east of the Mississippi was fairly known. But the western half of the continent was yet, geologically, a *terra incognita.* During the years 1853–1856 the several national surveys for proposed railroads to the Pacific Coast were accompanied by naturalists and geologists,

and the 13 quarto volumes of the Pacific Railroad reports contain some reconnaissance geology of the far west. Two other government surveys were accompanied by Dr. J. S. Newberry; one, the exploration of the lower part of the Colorado River, under Lieutenant J. C. Ives, in 1857–1858, the report being published in 1861; and the San Juan expedition under Captain J. N. Macomb, in 1859. But Newberry's report on the geology was not published until 1876, which lost him the public credit as the pioneer in the field explored.

During the civil war, science was submerged in strife. Following that struggle some of the released officers of the northern army found in the western explorations a field for their energy and courage. A striking illustration was the venturesome boat trip down the Colorado by Major J. W. Powell, in 1869, an adventure of remarkable daring, the dramatic story being told in his report, 1875.

The surveys which in a systematic way revealed to the public the scientific and scenic features of the Rocky Mountain region were those under F. V. Hayden, during the years 1869–1879. His personal studies of the west began in 1854.

The geological survey of the 40th parallel, under Clarence King, was during 1867–1879, the results comprising seven quarto volumes, 1870–1880.

Another series of contemporary exploration was under Lieutenant G. M. Wheeler, the geographical surveys west of the one hundredth meridian, in 1869–1879. The Powell surveys, personal during 1871–1874, became official in 1875–1879.

Then, in 1879 the several government surveys were combined into one strong organization, the present United States Geological Survey, which in purpose, financial support, influence and efficiency has never been equalled by any other scientific bureau.

It is not permitted to name here all the men of that splendid group participating in the early exploration of our western domain, with the paleontologists who reported on the fossils. Excepting the veterans, W. H. Holmes and J. J. Stevenson, they have all passed away, and are enrolled in the geologists' Hall of Fame.

The explorations in the western part of America, during the years 1870–1900, with the wonderful discoveries in structure, dynamics and in the evolution of the vertebrates, probably make the most brilliant chapter in the entire history of geology. The great development of the science in America is due to its wealth in geologic material. Archibald Geikie has said (2, Introduction, p. vii) that "had the study of the earth begun in the New World instead of the old, geology would unquestionably have made a more rapid advance that it has done."

Stratigraphic Geology

The vertical succession and relative age of American strata are now fairly well known, and only details and minor discoveries remain for future students. In Europe the stratigraphy has been worked out in detail. In the eastern continents the strata are known in a broad way, and any surprises are likely to be of new organisms, especially vertebrates, and of economic deposits.

One of the most debated stratigraphic problems during the later years of the century was the "Laramie." During the years 1872–1897 a lively discussion occurred over the age, whether Cretaceous or Tertiary, of the coal-bearing or "lignitic beds" of several separated areas in the Rocky Mountain region. This discussion involved many of the geologists who were active in the western exploration, and all the eminent paleontologists. Fortunately the debate never became so personal and acrimonious as the Taconic dispute. And it was useful, not only by inciting an intensive and careful study of all the characters of the rather unusual deposits, and in revealing the physical changes in that province, but also in developing some fundamental principles in stratigraphy. The deposits in the detached areas were found to close the supposed gap in the record between Mesozoic and Cenozoic times, changing from marine (Cretaceous) through brackish-water to fresh-water or lake deposits (Eocene Tertiary) as the area had been slowly lifted from sea level. The study also gave a clearer recognition of the relative value of different kinds of fossils, plants, invertebrates and vertebrates as horizon-markers, or evidence of relative age of the sediments; and emphasized the truth that geologic time is continuous, our time-divisions more or less arbitrary, and that somewhere the rocks may constitute a continuous and unbroken record from one great period into the succeeding period. In other words, that great geologic time divisions are not everywhere limited by physical disturbances or unconformities in the strata, but are to be distinguished, like epochs in human history, by the culmination of important physical changes, or by the development of some life-group in the evolution of life on the earth.[8]

An interesting discovery by the western explorations was that vast lakes existed in Tertiary time, formed at different levels during stages of the warping uplift of the Rocky Mountain belt. The thick deposits laid in these lakes hold the lignitic coals and include the Bad Lands (Mauvaises Terres) which show the most remarkable erosion forms. And to these freshwater deposits we owe the preservation of the wonderful mammals of the Tertiary.

[8] The story of the Laramie question has been interestingly told in Merrill's Contributions.

In addition to these "continental" lake deposits it has been found that extensive strata of sandstone and shale, formerly supposed to be marine or at least aqueous deposits, were really accumulated on land surfaces, presumably desert areas; sometimes by wind-action (eolian) and sometimes by storm-wash and sheet-flood from adjacent highlands. Such processes are now illustrated in the arid west. These continental subaerial deposits promise to be important in the complicated history, as they appear to be represented in our eastern Paleozoic record.

Intensive study of the structure and contents of sediments and of sedimentation processes, with contemporary land movements, has given importance to a principle vaguely recognized long ago. We now understand that definite strata may change laterally in character, organic contents, and even in time-relation, due to varying depth of the water and the changing relation to the shore. This subject of lateral changes in the character of aqueous deposits has brought new terms into our geological lingo, such as marine transgression and regression, overlap, offlap, etc. (See Grabau's "Text-Book of Geology," pp. 554–562.)

Paleontology

Paleozoology.—In Europe the life record preserved in the rocks was fairly known in 1848, and the remarkable Cretaceous reptiles and Tertiary mammals had been assigned their classic names. The subsequent European progress has been the filling of gaps and addition of details. The most important single discovery, of biologic interest, was that of the *Archeopteryx* in 1862, and a clearer specimen in 1873. This reptilian bird is sufficient proof of evolution, as a half-way link between reptiles and birds, and would have been a conclusive example for Darwin. An even better evidence for development of species is the series of steps in the evolution of the horse, in America.

In his presidential address at the 28th meeting of the American Association, 1879, Professor O. C. Marsh outlined the history of paleontology from ancient time. He recognized James Hall as the father of invertebrate paleontology in America. Hall's first volume was issued in 1847, and he completed 15 quarto volumes with 4,539 pages and 1,080 plates. This output is exceeded only by that of Joachim Barrande (1799–1883) in description of the fossils of Bohemia, who published 24 quarto volumes, and left material for five others.

If we choose one author as the founder of invertebrate paleontology it should be Lamarck (1744–1829), whose work covered the

early years of the nineteenth century; although Guettard gave considerable attention to fossils a half century earlier.

We regard Cuvier (1769–1832) as the founder of vertebrate paleontology and Thomas Jefferson as its earliest student in America. The early leader and authority was Joseph Leidy (1823–1891). In later years the famous men were: O. C. Marsh (1831–1899), E. D. Cope (1840–1897) and J. S. Newberry (1822–1892). The astonishing exhibits in our great museums are the wonderful reptiles, birds and mammals from the western deposits.

Paleobotany.—The history down to 1885 of this branch is found in Lester F. Ward's "Sketch of Paleobotany." He states that petrified wood was mentioned by Albertus Magnus in the thirteenth century, and by Agricola in 1558. The first notice of fossil leaves was in 1664. The earliest writer on fossil plants was J. J. Scheuchzer in 1709, with von Schlotheim as the earliest strictly scientific worker, during 1801–1820. Ward regarded the development of modern paleobotany as beginning with the use of coal as fuel, about the year 1800.

In 1848 Adolphe T. Brongniart was the recognized authority, his greatest work appearing in 1849. The European paleobotanists to 1885 form an extended list of names famous in the science. The famous Americans were Leo Lesquereux (1806–1889), J. W. Dawson (1820–1899), J. S. Newberry (1822–1892) and Lester F. Ward (1841–1913).

It is found that the progenitors of flowering plants lived far back in Paleozoic time, as a series of forms connecting with cryptogams. The conifers, the largest of our trees, date from the early Mesozoic; while our deciduous tree flora arrived in America in Cretaceous time.

Physiographic Geology; Cartography

Physiography or surficial geology, the science of earth-forms or geomorphy, began with Desmarest (1725–1815), DeSaussure (1740–1799) and especially with Playfair (1748–1819). But in America to the middle of the last century there was little scientific physiography. Descriptions of topographic features were empirical, with small reference to causation or to geologic processes. In 1856 the great Hitchcock in his essay on surface geology, which may be regarded as the beginning of American physiography, did not believe that the Connecticut River had carved all its narrower channel.

The subject was lifted to a scientific plane, with distinctive terminology, by Powell in his report on the Colorado Canyon district (1874), and by the papers of Gilbert and Dutton. The

modern leader, and the dean of American geographers, is W. M. Davis, who, with the help of the Association of American Geographers has made scientific geography a popular branch of education. "Baselevel" and "peneplane" are familiar words in scientific lingo.

The indispensable instrument in all field-work in geologic science is the map; and most useful is the one showing surface relief. The topographic maps of the public domain made by the U. S. Geological Survey, with some cooperation of the states, have been the greatest aid to geology of the last 30 years; and have been the means for popularizing physiography. It is difficult for us to realize the difficulties of the geologist in the early years without accurate maps, and often with no map of any kind. Frequently he had to make his maps. Now the field-worker has the aid of the handsomest maps that engineering science, skilled engraving and artistic printing can produce.

Petrographic geology

At the beginning of the nineteenth century the greatest authority on rocks was A. G. Werner (1749–1817). In the last fifty years the optical and chemical study of the crystalline rocks has become one of the most important and popular branches of science. The optical study became possible through the invention of the refracting prism, by William Nicol, in 1829, along with his production of transparent rock-sections. As a science it began with the memoir by Henry Sorby, in 1858, "On the microscopic structure of crystals." Optical mineralogy has developed with the progress in microscopical technique.

The science was developed by Zirkel and Rosenbusch in Germany, by Michel-Levy, Fouqué and Lacroix in France, and back in England by Teall and Harker. In America the science has been advanced by G. H. Williams, J. P. Iddings and L. V. Pirsson and eminent living workers.

This branch of geology laps over on dynamics, geophysics, vulcanism and Precambrian history. And it has many devotees. The Canadian men with their vast area of old crystallines and rich metallic deposits have emphasized the subject since the days of William E. Logan (1798–1875), who was the director of the Canadian survey from 1842 to 1870, and was the founder of American Precambrian geology.

To-day the science of petrography is changing from the descriptive to the interpretive stage, with its latest field the study of sediments. Its highest development is the optical work in the geophysical laboratory.

Glacial Geology

The romantic story of the development of glaciology in America, and the persistence of cataclysmic notions of the "drift," has been told in the *Proc. Amer. Assoc.*, Vol. 47, also in the *American Geologist*, Vol. 22, pp. 154–189.

Glacial science began in 1841 with Agassiz's paper before the Geological Society of London, and in America the discussion began over Hitchcock's address as retiring president of the Association of American Geologists, in 1842. In that address and in other writings

> Professor Hitchcock seemed to declare his adherence to the glacial hypothesis, as applied to America, with as little hesitation and qualification as would be expected of a careful man of science in espousing a new theory that antagonized the prevailing belief and prejudice of his fellow-workers. It is evident from subsequent records that his utterances were accepted at the time as committing him to the acceptance of the theory of Agassiz. But unfortunately . . . the circumstances and scientific forces of that time did not allow him to stand upon the advanced ground he had taken.

There were forces opposing the new theory which were not of scientific character.

> Agassiz was a comparatively young man and quite unknown in geology except for his studies of glaciers. How could his opinion weigh against those of the giants in geology? Another power, which will scarcely appear in the scientific writings of the time, but which was a great conservative force, was theological opinion. All hypotheses invoking water as the drift agency might be harmonized with belief in the Noachan deluge, but the Bible gave no countenance to an ice deluge. To explain it away was little better than heresy. . . . Furthermore, the diluvial hypotheses were unduly deductive, and like all opinions not based on observational or inductive evidence did not readily yield to arguments derived from facts. The older geologists had made up their minds and that settled it.

The acceptance of the glacial theory by any number of Americans could not have been earlier than the personal advocacy by Agassiz and Guyot in 1848 tc 1850, although in some qualified form it was adopted by independent thinkers like Conrad and Vanuxem. The general acceptance of the theory, and the use of it as a basis for systematic work and investigation, required 20 years more.

This branch of geology reaches over to meteorology on one hand and to dynamics and geophysics on the other. Glaciers are meteoric phenomena, but are geologic agents. The surface features produced directly or indirectly by glaciation are exceedingly interesting, and are the most effective for popular appeal in regions where they occur. To geologists the subject has lost its element of mystery. We now see that continental ice-fields are as natural as lakes, and normal to areas of excessive snowfall instead of rain. They are essentially local phenomena, dependent on temperature and pre-

cipitation. The latest American continental ice-cap had its origin and its center or radial outflow in southern Quebec. As yet we do not know how much effect a supposed greater elevation of the land had on the initiation of the glacier.

We regard the present time as a part of the Glacial Period, and perhaps as an interglacial epoch. There are good reasons for believing that since the Quebec glacier disappeared the climate of North America and of western Europe has been much warmer than it is to-day. The cause or causes of change in world climate remains a problem. It may be related to the variable content of the atmosphere, especially the carbon-dioxide, with the cooperative factors of continental elevation, paths of cyclonic storms and oceanic circulation. There is little scientific basis for appeal to extra-terrestrial forces for explanation of long-period differences in climate. The problem must be studied as a geologic matter.

The most important discovery in glaciology is the fact of heavy glaciation in former geologic periods, even as far back as the pre-Cambrian. The greatest and most wide-spread glaciation appears to have been in the southern hemisphere, in Permian time, at the close of the long Paleozoic Era. It is suggested that this may be related to the impoverishment of the atmosphere in CO_2, by the withdrawal of carbon in the accumulation of the vast coal deposits. Here glaciology passes over into climatology.

Since the Quebec glacier disappeared the glaciated area has risen, in dome-shaped uplift, at least 1,000 feet at the center. This suggests a causal relation of the land uplift to the unloading from the area of 10,000 feet of solid water. This implies a high elevation of the area before it was loaded and depressed. Here the study passes over into geophysical geology, as an argument for isostasy.

Cosmic Geology

When the Copernican theory was generally accepted, in spite of persecution which lasted far into the nineteenth century, a scientific cosmogony was sought, to express the new knowledge of the structure and motions of the solar system. Suggested by Swedenborg and outlined by Kant, the "nebular" hypothesis was given standing and authority by Laplace, assuming certain primitive conditions. Probably no philosophic conception has ever received such universal acceptance by the modern world as the Laplacian theory. Yet it is not true. It has been conclusively shown by Professors Chamberlin and Moulton that the theory breaks down at every point where attacked by present-day physics and kinetics. The conception of an originally molten globe must also be discarded.

A substitute for the old philosophy, which was good for its day,

has been formulated by Professor Chamberlin. His planetesimal theory builds the earth by the slow infall or accretion of cold particles (planetesimals), and keeps the growing globe always cold at the surface.[9]

This subject is of fundamental importance in geology, because few topics can be carried to conclusion without reference to the origin of the globe. And geologic science has been seriously hindered by the false conception of a molten globe. This new conception of the earth, as having been slowly built by accretion of cold matter, always cold at the surface, and containing within the growing mass all the materials for its slowly formed envelopes—the ocean and atmosphere—gives a rational basis for solving many geologic problems which were insoluble under the old theory.

A few examples of such problems are: (1) the great shrinkage of the globe in late geologic time and under present temperature; (2) the origin of the ocean and atmosphere; (3) the primal source of the vast storage of carbon in the later rocks; (4) source of the enormous volume of volcanic water; (5) the climatic variations during geologic time; (6) the great length of time required for organic evolution.

A brief comparison of the old and new theories will show their fundamental opposition. The old hypothesis assumes an originally hot globe with shrinking on account of cooling. The new regards the globe as originally and always cold at the surface, and the interior heat as the product of gravitational condensation. The old view requires continuous cooling of the globe, while the new allows the conception of increasing internal heat. The old makes the earth of largest size at birth, and of diminishing volume by loss of heat, while the new regards the earth as beginning with a small nucleus and slowly growing by surface accretion; but with large reduction of volume by compression and expulsion of vapors during and subsequent to growth. The old postulates a primal, heated atmosphere and ocean. The new derives the fluid envelopes from the earth's interior by a slow process of expulsion due to heat and pressure.

That the great majority of educated people, and perhaps most of the geologists, yet adhere to and refer to the discredited "nebular" theory, with its molten earth, only illustrates that scientific men are conservative, like other people, and slow to change long-accepted views. Moreover, the attention of the whole world has been diverted from philosophic science and is absorbed in applied

9 A statement of the planetesimal theory is given in Chamberlin and Salisbury's "Geology," Vol. 2, and in many of Professor Chamberlin's writings. On its application to geology see Bulletin of the Geol. Soc. Amer., Vol. 15, 1904, pp. 243–266.

science, business and politics. It must be realized that knowledge of geologic science is the possession of only a small portion of Americans and Europeans, while a yet smaller number have any special interest in it.

Geophysical Geology

Perhaps the liveliest branch in present-day geology relates to the structure, composition, stresses and movements within the earth.

Sir John Herschel (1792–1871) recognized the sinking of oceanic areas under loading by sedimentation, with the consequent rise of continental areas. As early as 1847 Dana discussed the effects of the earth's contraction from the supposed molten state, and the resulting relief features of the globe. In 1857, at the Montreal meeting of the association, James Hall discussed the subject of crustal movements and mountain formation, which caused debate and criticism, but the paper was ahead of time and was not published until 1882.

Opinions down to the year 1896 on the mechanics of the earth's crust, as shown by earthquakes, mountain structure and continental relief, will be found in three addresses by Joseph LeConte; his presidential address to the association in 1893; his memoir of Dana, 1895; and his presidential address to the Geological Society in 1896.[10]

Le Conte's views, like those of Dana, were based on the conception of the globe cooling and solidifying from a molten and incandescent state.

In 1880, as a result of his study in the high plateaus of Utah, Major C. E. Dutton formulated his theory of isostasy, which postulates an equilibrium of weight or pressure in the earth's crust, with readjustment by subcrustal flow when adjacent areas became unbalanced by loading or unloading. The common illustration at the present time is the unloading by erosion of elevated areas and the piling of the detritus as a load on delta tracts. In essentials isostasy is generally accepted as a working theory. It finds recent illustration in the post-glacial rise of the glaciated areas of America and Europe.

Earthquake vibrations indicate that the entire globe is solid and of high density. As the average specific gravity or mean density of the globe is 5.6, while the observable crust is only 2.8, it follows that the deeper mass has a high compensating density. Whether this greater density is due to compression or to heavy, or metallic, materials is the problem.

[10] Bull. Geol. Soc. Amer., Vol. 7, 1895, pp. 461–474; Bull. Geol. Soc. Amer., Vol. 8, 1896, pp. 113–126; Bull. Geol. Soc. Amer., Vol. 26, 1915, pp. 47–57.

Geologists and physicists have now under intensive study the mechanics of movements in the earth's crust and the formation of mountains by deformation of strata.

Evolution

By 1848 physical evolution, the development of the globe by natural processes, was generally accepted by educated and free-thinking men. But the acceptance of organic evolution awaited the long discussion following Darwin's work.

The study of fossil organisms clearly indicates the development of new forms from old. Living forms, both plant and animal, represent the diverging branches of the life-tree, of which the trunk and the connections are buried in the dead past.

The fossil proofs of evolution are more conspicuous, or at least better known, in the vertebrates, because the latter are more familiar to us in their structure and relations, but students of the invertebrates find that many groups, as the brachiopods, cephalopods and echinoderms, clearly attest the evolutionary process.

The vertebrates are closely related in progressive series. The evolution of birds from reptiles is established by transition forms, such as the dinosaurs, the toothed birds and the linking *Archeopteryx.* The exploration of our western domain has given to paleontology a most surprising abundance of related mammalian remains, which prove the development by inheritance of characters of the various groups of living mammals This is particularly evident in the ungulates (hoofed mammals). The most striking example is the evolution series of the horse, which in America during Tertiary time evolved from a diminutive five-toed creature to the modern horse, possessing the most highly specialized foot, with a single digit. The even-toed ungulates, especially the ruminants, also give excellent illustration of evolution.

The history of life on the earth, as recorded in the rock-record of scores of millions of years, establishes the truth of evolution since Cambrian time. But that is only the latter part of the process, for the Cambrian organisms represent perhaps more than half of life development from primitive forms. The record of the long earlier stages of organic evolution is lost through the alteration and metamorphism of the pre-Cambrian strata.

The origin of life, or its initiation on our planet, yet remains a problem for biochemistry and scientific philosophy.

All future discoveries will only accumulate proofs of evolution. The devotees of unscientific beliefs and supernaturalism will receive no comfort from discoveries to come. Evolution has passed the theoretic stage and must be recognized as fact. That multitudes

of people do not yet accept it does not affect its status. Scientific truth is not dependent on belief nor to be decided by majority vote. Some people even to-day deny the rotundity of the earth. The cause or method of evolution is uncertain.

While people educated in science may accept evolution as true for all forms of life below man, many of them, and perhaps even some professional men of science, react against including man in the natural process. The false expression "from the monkey" is partly responsible for the prejudice. But the very narrow gap between the higher living primates and the genus Homo may be closed almost any day by new discoveries. Already we have a number of suggestive semi-human fragments. It should be realized that only a small part of the world has been carefully examined, and a large part of the orient, the probable field of human development, not at all. America and western Europe have been explored, but the vast areas of Asia and Africa are the hopeful fields. The "missing link" may not long be missing.

Economics: Present tendency

In later years the United States Geological Survey and most of the state surveys have been compelled to defer to the world-dominating spirit of commercialism. The greater part of all the literary output of the surveys now relates to the economic resources and their utilization. This is in unhappy contrast with the early years of the national survey, when the dramatic exploration of the great west, and the inspiring reports of Hayden, King, Wheeler, Newberry, Powell, Gilbert, Russell and others, with the paleontologic memoirs of Meek, Leidy, Cope, Marsh, Newberry and Lesquereux had a popular appeal to a multitude of readers. The work and reports of those years were educational in the true sense.

The progress in economic geology has largely been the discovery and exploitation of our stores of iron, coal, hydrocarbons, with admirable study of water supplies. Only the last is renewable. Of course modern civilization requires steel and fuel, but it is not necessary to develop our resources so rapidly and wastefully, with little regard for posterity. The exploitation has too largely been not for immediate human need, but for unreasonable private profit. In justice to the national and state surveys it must be said that their influence has been used for conservation of mineral resources; but unfortunately their function to point out the useful products is not accompanied by sufficient power to control production and waste.

In the present darkness the New York survey stands as an intellectual and altruistic beacon. During the 60 years of direction

by James Hall, the few years by F J H Merrill, and the 18 years by John M. Clarke, the State Museum and the State Geological Survey have held steadily to their function of serving the scientific interests of all the people Most of the vast literature issued from Albany during 80 years is "pure science," in the sense of being non-commercial Yet New York has important economic mineral deposits, and it is possible that the excellent economic work of the New York Survey might be somewhat increased in proportion to the non-economic

Problems

The "unknowns" of the earth-laboratory have been reduced to a few groups of questions. The stratigraphic record of the earth's history since pre-Cambrian time, which was the early geology, now offers only details for future study In the life history the larger elements are established

The inevitable question, "How long ago?" can not yet be answered The length of geologic time is not of practical importance, and is so great that, if we knew, it could not be appreciated However, some time we may yet discover a yardstick for cosmic and geic time. Fragments of glacial time, and perhaps of more ancient periods, may be estimated by the diurnal and annual periodicity of sedimentation By the lowest estimate the stratified rocks represent over 100,000,000 years

Some of the geophysical problems have been noted. The composition, structure, temperature and movements of the earth's mass are live topics Allied to these is the group of problems of the Precambrian, like metamorphism, the ancient effects of which are evident in the exposed crystalline rocks. Under the planetesimal theory the volcanic phenomena and the deep ore deposits are less mysterious. Earthquakes, explained by modern physics and measured by instruments, give suggestion of the earth's interior conditions

The cause and behavior of the movements in the crust of the globe is an interesting and yet elusive problem, of which the formation of mountains by compression or folding is an important element. Another easily appreciated problem is the causation of climatic variations during all recorded time

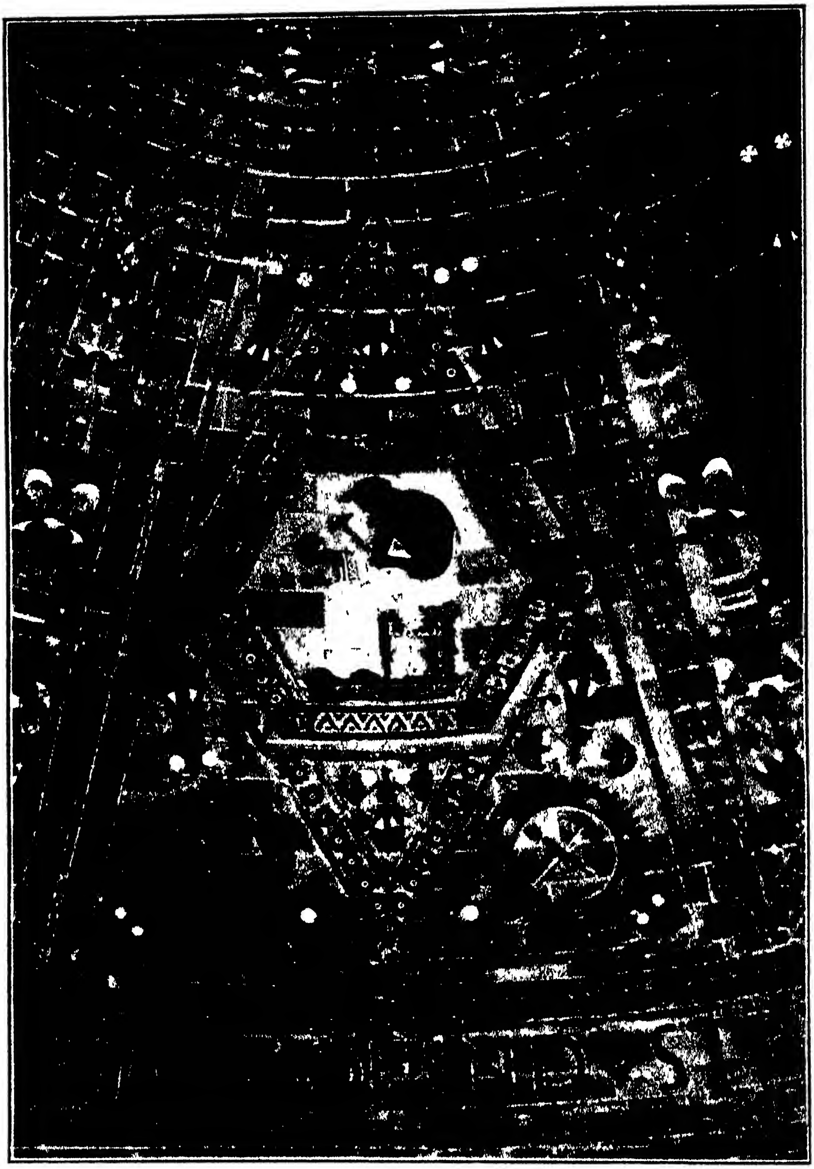
All these questions are related to the fundamental problem of the manner of formation of the globe. It is confidently believed that the theory of slow growth by cold accretion will facilitate the solution of nearly all geologic problems.

All "progress" is a matter of relativity. In his address in 1841 Edward Hitchcock said:

And now, looking back . . I am astounded and delighted at the progress of American geology, and it seems to me more like a dream than a reality, . .

This was spoken when the Association of American Geologists was one year old, and before the publication of the epoch-making reports of the New York survey and other important state reports. His thoughts in 1848 are not recorded

We may query if the experts in earth-science 75 years hence will regard our present status with the respectful superciliousness which we have for that of 1848. It does not seem probable. But possibly some of the youngest readers of this article can make report in 1998



DECORATION ON THE DOME OF THE NEW ACADEMY BUILDING

Emblematic figures representing all the branches of science decorate the interior of the dome of the new academy research building just completed in Washington as the home of the National Academy of Sciences and the National Research Council. A dedication of the building to science is contained in the inscription, partially reproduced in the photograph: "To science, pilot of industry, conqueror of disease, multiplier of the harvest, explorer of the universe, revealer of nature's laws, eternal guide to truth." The portion done in gold, purple and other colors shown in the photograph is a classical representation of geology, a seated figure tapping a rock with a geologist's hammer. The medallions show one of the best known fossils, a trilobite, and the familiar crossed hammer and chisel symbolic of mining.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E SLOSSON

SCIENCE SERVICE, WASHINGTON

COOPERATION IN LOW LIFE

THE more we learn of animal and plant life, the less it seems like a chaos of incessant conflict and carnage, and the more it seems like a universal scheme of unconscious cooperation. The struggle for existence is real, war to the death, to the strongest belong the spoils, every one for himself, the weak to the wall, and all that But also we find on closer inspection more than we thought of mutual aid, not only between individuals of the same family or pack or species, but between species of the most widely different sorts, and sometimes it turns out that what seem to be inveterate enemies are actually involuntary allies

Many an animal owes his success in life to the unrecognized cooperation of the humblest creatures For instance, it is a great advantage for fishes and other marine forms to have a lighting system for use at night and in the depths of the sea Some have glands that secrete the two kinds of chemicals that produce light when mixed. But many others depend upon luminous bacteria, of which some thirty species are known These live in certain glands or stream through tubes which serve as lamps to the lost. The cuttle-fish has gone so far as to fix up a reflector behind and a lens in front of its light-giving colony of bacteria In the glow-worm the bacteria are also present in the beetle's eggs, which are likewise luminous.

Bacteria and other micro-organisms are often found aiding digestion by attacking substances that their hosts would find too tough to tackle alone. Vegetable foods, for instance, contain more or less cellulose, wood fiber, which is extremely indigestible stuff, and even cattle could not get nutriment out of it if it were not for a process of internal fermentation The so-called "white ants," termites, terror of the tropics, get their living by eating the insides out of furniture and books, yet they can not digest such cellulose. What they do is to chew it up and turn it over to fungi, which thrive on it and then the termites feed on the fungi.

Flies lay their eggs in meat, but the larvae when they hatch out can not digest the meat without the help of the bacteria in their intestines Peas, beans and alfalfa owe their power of utilizing the nitrogen of the air to the bacteria that colonize on their roots in the form of nodules Most plants can not use free nitrogen but have to have it served up to them in the form of salts such as nitrates The root nodules therefore might be called the Muscle Shoals of the plant world, but that would not be a fair name for them since they are working.

The tubers of the potato are due to a parasitic fungus Potato seeds planted in sterilized soil do not produce tubers, but when the fungus is allowed to invade the soil tubers start to grow. If you should ask a young potato plant whether it wanted to be infected by a fungus, and if the potato were as intelligent—or rather as unintelligent as men are—it doubtless would reply that its pristine purity must remain unimpaired by any parasite. Yet that refusal would deprive the plant of its chance of per-

FOUNDERS OF SCIENCE

Men of science who have contributed most to the advancement of science during the centuries, portrayed in bronze relief on the front of the building of the National Academy of Sciences and the National Research Council, erected in Washington at a cost of $1,450,000 and dedicated on April 28 The photographs here reproduced are copyrighted by the National Academy of Sciences and released by Science Service

Francis Galton (1822–1911), English man of science, founder of eugenics; Josiah Willard Gibbs (1839–1903), American mathematician and physicist who applied the principles of thermodynamics to chemistry, Hermann von Helmholtz (1821–1894), German physiologist and physicist, Charles Darwin (1809–1882), the great biologist; Sir Charles Lyell (1797–1875), who laid the foundation of modern geology, Michael Faraday (1791 1867), English chemist and physicist, who discovered magneto electricity and the magnetization of light

FOUNDERS OF SCIENCE

Alexander von Humboldt (1769–1859), German philosopher and traveler; John Dalton (1766–1844), English chemist who originated the atomic theory of matter; Jean Baptiste de Lamarck (1744–1829), the French naturalist; James Watt (1736–1819), Scottish inventor of the condensing steam engine; Benjamin Franklin (1706–1790), American patriot and physicist; Christian Huygens (1629–1695), Dutch physicist and astronomer who proposed the wave theory of light and discovered Saturn's rings.

ennial life and, what's worse, deprive us of potatoes It has been found that orchid seeds do not sprout unless a certain fungus is present, and each species of orchid has to have its particular species of fungus.

The lichen on a tree or stone seems to us a simple single growth, but it really is a partnership of two very dissimilar forms of vegetation, a plant and a parasite, an alga and a fungus Which is to be regarded as the host and which the parasite, which was originally the patient and which was the disease, can hardly be determined since the relation varies in different lichens, and the two strange associates have been living together so long now that they play into each other's hands and could hardly stand it to live alone.

So it happens that a plant or animal gets used to a chronic disease and finds it advantageous, and a parasite that came to prey remains to serve Dr. Nuttall, of Cambridge, who at the Liverpool meeting of the British Association for the Advancement of Science gave these and many other instances of cooperation, or symbiosis as biologists call it, thinks that they all began as cases of parasitism, but that the conflict between the associated organisms ended in mutual adaptation The two enemies become allies and the parasite becomes a partner

TAMED INVENTIONS

COMING inventions cast their shadows before. Some of the most useful of the gifts of science were first revealed to mankind in a malevolent rather than a benevolent aspect But even the most destructive agencies may in the course of time be brought into the constructive service of the human race. As the wolf was tamed into the faithful dog and the wild elephant converted into a beast of burden, so man may tame the engines of war and extract medicaments from the most baneful drugs

Steel, man's most useful metal, made its appearance in the form of swords and spearheads for the killing of man Now we employ it for the skeleton of skyscrapers and steamships

Petroleum was first employed as "Greek fire" for setting ships on fire Now it is employed as fuel for the propulsion of ships

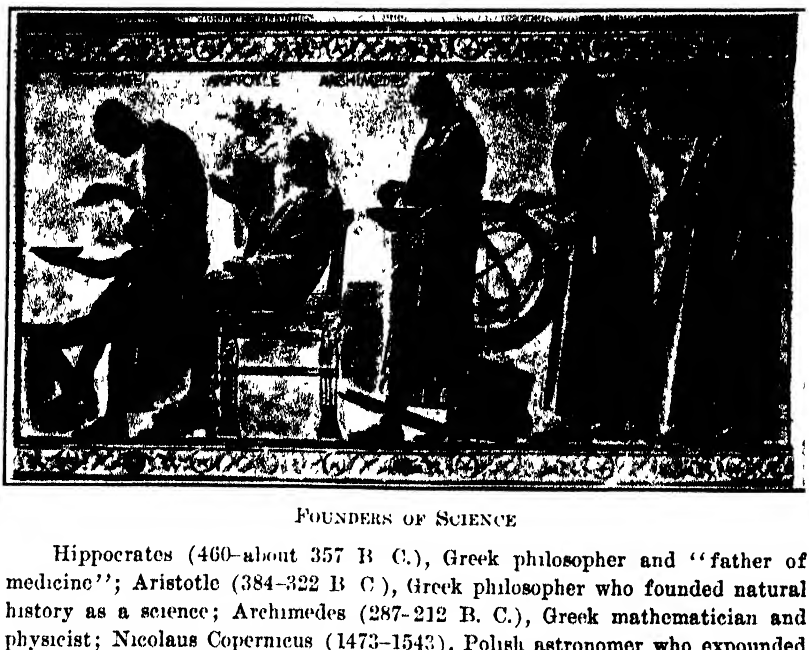
The horse was employed upon the field of battle long before he was put to work upon the harvest field. He was first hitched to a war chariot and only later was he set to the humble and useful task of pulling a plow. Judging by the Egyptian and Assyrian inscriptions, the chariot was the first wheeled vehicle, but this developed in the course of centuries into the cart, the carriage and the car.

The most efficient of the ancient road builders, more efficient indeed than most modern peoples, were the Romans, and their famous system of highways, connecting the frontiers of the empire with the forum of the capital, was designed for armies, not agriculturists

It has often happened in history that what was designed to kill is retained to cure. Many of our modern medicines were employed by savages for poisoning their arrow points. Strychnine and aconite had this ill-omened origin Another arrow poison, obtained by the savages from cassava juice, is hydrocyanic acid, which in the hands of the modern metallurgist extracts nine tenths of the gold supply of the world. Arsenic, which during the Renaissance was the fashionable means of poisoning people, is now used for the more laudable purpose of poisoning plant pests and the parasites of man. Distilled alcohol, introduced by the alchemists under the misleading name of the "elixir of life," has done untold harm

FOUNDERS OF SCIENCE

Galileo Galilei (1564–1642), the Italian astronomer and physicist; Leonardo da Vinci (1452–1519), the Italian painter, architect, sculptor, engineer and anatomist; Hipparchus (about 150 B C), the greatest astronomer of antiquity, a Greek who discovered the precession of the equinoxes, founded trigonometry and compiled the first star catalogue, Democritus (about 400 to 357 B C), the Greek philosopher who advanced a theory of the formation of the universe by atoms in motion; Thales of Miletus (640–546 B. C.), the Greek physical philosopher, founder of Greek astronomy and philosophy



FOUNDERS OF SCIENCE

Hippocrates (460–about 357 B C.), Greek philosopher and "father of medicine"; Aristotle (384–322 B C), Greek philosopher who founded natural history as a science; Archimedes (287–212 B. C.), Greek mathematician and physicist; Nicolaus Copernicus (1473–1543), Polish astronomer who expounded the planetary system, Andreas Vesalius (1514–1564), Belgian anatomist; William Harvey (1578–1657), English physician who discovered the circulation of the blood.

to the race Yet when our gasoline supply runs short, alcohol may prove to be our main reliance for autos and airplanes. Once the world stops drinking it we will have alcohol to burn.

We owe our wireless to the late war, and the art of aviation, which played an important part in that conflict, has not yet found a place of importance in civil life. Government itself is a war baby, born from the need of unified control in time of danger. The earliest rulers were the chiefs who defended their folk against attack or led them on predatory raids against their neighbors for the procurement of booty, especially women and children

Government, once started as a war measure in emergencies, proved useful for the maintenance of order and the promotion of the general welfare, and hence came to be regarded as indispensable to civilization But war remains the principal function of government even in the most peaceable of nations Our own federal government in 1920 spent 93 per cent of its revenues on wars, past, present and future, while devoting one per cent. to the scientific research and developmental work.

Never before has the world seen such feverish activity in scientific investigation and invention as during the Great War, never such liberal governmental support, never such enterprise and self-sacrifice on the part of the citizens And so it has often been in the past Mars has always been able to enlist the energies of man with more success than Minerva or the Muses. Shaw, who sometimes assumes the rôle of the devil's disciple, has in his "Man and Superman" put into the mouth of Mephistopheles a caustic comment on war as a stimulus to man's inventive powers. "I have examined Man's wonderful inventions And I tell you that in the arts of life man invents nothing; but in the arts of death he outdoes Nature herself, and produces by chemistry and machinery all the slaughter of plague, pestilence and famine The peasant I tempt to-day eats and drinks what was eaten and drunk by the peasant of ten thousand years ago, and the house he lives in has not altered as much in a thousand centuries as the fashion of a lady's bonnet in a score of weeks But when he goes out to slay, he carries a marvel of mechanism that lets loose at the touch of his finger all the hidden molecular energies, and leaves the javelin, the arrow, the blow pipe of his fathers far behind. In the arts of peace man is a bungler. I have seen his cotton factories and the like, with machinery that a greedy dog could have invented if it had wanted money instead of food. I know his clumsy typewriters and bungling locomotives and tedious bicycles; they are toys compared to the Maxim gun, the submarine torpedo boat. There is nothing in man's industrial machinery but his greed and sloth; his heart is in his weapons."

But, as we have seen, the bright ideas that have been struck out of man's brain in the clash of conflict may persist to enlighten the race "God hath made man upright but they have sought out many inventions" for the purpose of doing injury to their fellow-men, but often these have, like Balaam's curse, turned out to be blessings. Though we may regret that science should so often show her sinister side, yet we must agree that civilization does sometimes go forward by riding on a powder-cart.

CHEMISTRY AND THE ALPHABET

WHEREIN is modern civilization superior to ancient civilization and primitive barbarism? In what respects is the man of to-day ahead of his primitive forebears? Probably not in physique or mentality. If the winners of the Olympic games could be matched against our own athletic champions, we should not know which

FOUNDERS OF SCIENCE

Sadi Nicolas Leonard Carnot (1796–1832), French engineer and physicist; Claude Bernard (1813–1878), French physiologist; James Prescott Joule (1818–1889), British physicist who determined the mechanical value of heat; Louis Pasteur (1822-1895), French scientific man who founded the science of bacteriology, Gregor Johann Mendel (1822–1884), Austrian priest who discovered the law of inheritance which bears his name, James Clerk Maxwell (1831–1879), Scottish physicist who propounded the electro-magnetic theory of light.

FOUNDERS OF SCIENCE

René Descartes (1596–1650), French mathematician and philosopher who invented analytic geometry, Sir Isaac Newton (1642–1727), British physicist and mathematician who discovered the law of gravitation; Carolus Linnaeus (1707–1778), Swedish botanist who devised systems of classification for animals and plants; Anton Laurent Lavoisier (1743-1794), French chemist, called the "father of scientific chemistry"; Pierre Simon Laplace (1749–1827), French mathematician and astronomer who formulated the nebular hypothesis; Georges Cuvier (1773–1838), French naturalist who founded comparative anatomy and vertebrate paleontology; Karl Friedrich Gauss (1777–1855), German mathematician.

side to bet on. If a Binet-Simon-Stanford intelligence test were put to a Roman consul, a Phoenician merchant, or an Egyptian priest, I presume he would score high.

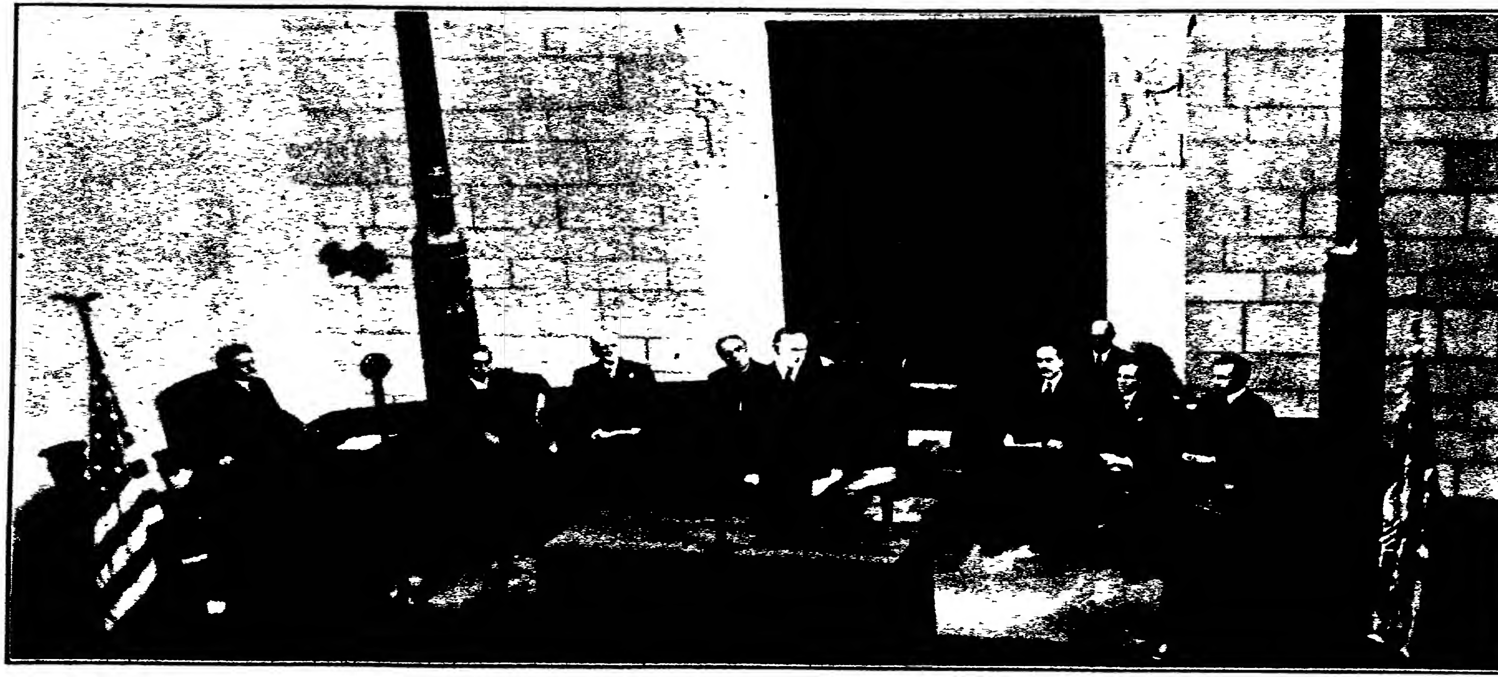
But a man in modern times, even though he may be comparatively weak in body and dull in mind, knows more and can do more than the strongest and the brightest of men in former times. He knows more because he has at his command the accumulated knowledge of the ages, selected, tested and arranged for his benefit. He can do more because he can supplement his feeble muscles with engine power. He can travel fifty times as fast, accomplish a hundred times as much work in a day, lift a weight a thousand times as heavy, and make his voice heard ten thousand times as far. Both these advantages, the physical and the intellectual, he owes to chemistry. It is chemistry that has given him the power that runs his engines and the metals that make his machines. It is chemistry that has given him books; the paper, the ink, the type and the alphabet.

It is a strange thing, and when you think of it a very lucky thing, that substantially the same alphabet is used nearly all over the world, in Europe, the Americas, Australasia and a large part of Asia and Africa. How did it happen? Why should we not get along without an alphabet as the ancient Egyptians did and as the Chinese do? Ask any schoolboy to whom we owe the alphabet and he will reply, if he be of the Macaulay kind that answers rhetorical questions offhand, that the Phoenicians invented it. But if you ask him the natural next question why the Phoenicians, who left us no literature, should have yet supplied the means by which our literature is expressed and preserved, you will probably stump him. That is because history has not been interpreted from a chemical standpoint.

The Phoenicians invented the alphabet because they needed it in their business. And what was their business? Chemical industries and commerce in chemical commodities. With a trade extending from the foggy and barbarous islands of northwestern Europe where tin was mined to the sunny islands of southeastern Asia where spice was grown, with dealings in dozens of different languages and accounts to keep in varying rates of exchange, the Phoenicians had to cut down the cumbrous hieroglyphics to simplified forms and to reduce their number from a thousand to twenty-two. The basis of almost all the alphabets of the world is the commercial code of the Phoenician traders.

And how did the Phoenicians gain their commercial supremacy? How did the Twin Cities of Tyre and Sidon get their start? Let us take the story as it stands in the ancient version.

Once upon a time Hercules was engaged in his favorite pastime of courting a nymph. Tyrus was her name, and as she walked along the Syrian shore, Hercules followed her, and his dog followed him. When he caught up with her he urged his suit, but she continued to refuse. Suddenly she interrupted his impassioned plea with the irrelevant remark: "Oh, just look at that dog!" Hercules looked around crossly and saw that the dog's mouth was dripping with purple saliva. The dog had strayed away, since he was not interested in the conversation, and had bitten into a shellfish on the beach, *Murex trunculus* was its name, though probably none of the three knew it. Hercules tried to resume the conversation where it had been interrupted, but the nymph's eyes were fixed, as though fascinated, on the dog's mouth. Finally she turned to her suitor and said, "I tell you what, Herky, I'll say 'yes' to you, if you will dye me a dress of the lovely purple of that dog's tongue." Probably she said it to get rid of him, but you know Hercules was not the man to take a dare. So he set to



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DEDICATION OF THE NEW BUILDING OF THE NATIONAL ACADEMY OF SCIENCES

President Coolidge addressing the meeting of the National Academy of Sciences on April 28, when the new building in Washington was dedicated. On the left is Professor A. A. Michelson, professor of physics at the University of Chicago, president of the academy. On the right are the three speakers in addition to President Coolidge—Dr. John C Merriam, president of the Carnegie Institution and vice-president of the aca[illegible]y [illegible]r. Vernon Kellogg, secretary of the National Research Council, and Dr Gano Dunn, chairman of the National Research Council

work to get out the new dye, and it proved to be one of the hardest of the labors of Hercules. For he had to pick out from each shell the tiny sac that contains a few drops of the liquid from which the dye stuff is extracted. But finally Hercules succeeded in dyeing a robe in royal purple to the satisfaction of his lady love and she fulfilled her promise. Presumably, although the legend does not definitely say, they were married and lived happily ever after. At any rate the city that was founded on the industry thus inaugurated took from her its name of Tyre, and made Hercules its patron.

Now for the story of the Twin City, Sidon. A galley of Phoenician merchants were skirting the Syrian coast with a cargo of natrium, that is, natural carbonate of soda, doubtless mixed with lime. It came dinner time and it not being safe or handy to build a fire on board the row boat, they tied up to the shore of the mouth of the river Belus. But where they landed was a sandy beach and not a stone was to be found on which to set the kettle. So one of the men went back to the boat and got some blocks of the natrium and with them built up a rude stove on which to support the cooking utensils. The fire must have been a hot one for when the merchants packed up they found that the sand and soda had fused together to form a new and pretty substance, glass. Having a keen eye for marketable curiosities, they started in the glass business and on this chemical industry was founded the city of Sidon. The Phoenician merchants found that glass beads would readily pass as currency with savages, such as the British. From them they got tin in exchange, which, mixed with nine parts of copper, made the best of bronze for their weapons or ornaments.

Now these stories may be fiction, but they are really fable, for they convey the fundamental fact that these, the Twin Cities of Tyre and Sidon, the richest and most prosperous of their time, were built up on the two great branches of chemical industries, metallurgy and dyeing. They ran their own lines of ships and worked their own mines of gold and galena in Spain, of sulfur and alum in Melos. They imported raw silk and cotton from India and wove and dyed themselves so as to get the profit of the entire process.

If you will refer to the first Book of Kings or the Second Book of Chronicles, you will see how much Hiram, King of Tyre, contributed to Solomon's temple by the chemical arts of his people. The Phoenician ships served as shuttles to bind the nations together by mutual commerce and a common alphabet.

TWO THOUSAND TIMES SWEETER THAN SUGAR

If you find that you have to order sugar oftener than you like, just tell or telephone the grocer to send up a pound of alpha-anti-aldoxine of perillaldehyde. If he fills the bill you will find that this single pound will go as far as a ton of common sugar, and is likely to last the family some twenty years by which time the price of sugar may have fallen to a reasonable level.

Probably the grocer will say, as usual, that he is just out, but has something just as good. Which, as usual, will not be true, because there is nothing just as good, or at least none has yet been discovered, or anyhow been tasted. For, curiously enough, the above-mentioned compound, whose name I shall not repeat since space is short, was known ten years before anybody thought of tasting it. It was first made in Germany in 1910 and duly analyzed and described. But chemists are not in the habit of licking off their fingers whenever they get something on them in the laboratory. If a freshman student has that propensity he gets cured of it before the

end of the term without the teacher's saying a word to him about it. So it was not until 1920 that a chemist, making the aforesaid compound, found to his surprise that it was sweet, and surprisingly sweet at that. He was a Japanese named Furukawa, and I don't know whether he licked his fingers or not, but if he did it was a lucky lick, for he rushed off to the patent office and got the stuff patented as a sweetener. It is made from the essential oil of a plant known to the Japanese as "Shiso" and to botanists as "Perilla."

The interesting thing about it from a chemical standpoint is that it is not in the least like any of the natural sugars in structure, although it is composed of the same elements, carbon, hydrogen and oxygen, the common elements of all foods Yet if the same number of atoms of the same elements, attached to one another in the same way, are arranged in a slightly different position the resulting compound is not sweet at all.

The record for sweetness has hitherto been held by saccharin, which was made by Ira Remsen, afterwards president of Johns Hopkins University, while he was a student It is a coal-tar derivative, and also no relation of the sugars, yet it is several hundred times sweeter than cane sugar. Just how much sweeter depends upon the degree of dilution. If the water solution is strong, one part of saccharin equals 200 parts of sugar. If more water is added the sugar solution loses its sweetness in proportion to the dilution, but the saccharin holds out better so that 700 times as much water can be added to the saccharin solution as to the sugar solution before it ceases to taste sweet.

Dulcin, another coal-tar compound, is about half as sweet as saccharin, yet, strange to say, the addition to saccharin of only 50 per cent. of dulcin will nearly double its sweetness A third coal-tar compound, about a hundred times as sweet as sugar, goes under the name of glucin.

Another super-sweet was reported at the recent meeting of the American Chemical Society by A. W. Dox and Bruce Houston, of Detroit. This is some 300 times sweeter than sugar and is altogether unlike any of the others in structure It contains chlorine and is called "hexyl-chloro-malonamide," but if it is ever made marketable, it must be given a name that is less of a mouthful. A slight change in the make-up of its molecule produces a compound that is not sweet but intensely bitter. The tongue is a good chemist. Yet, having been trained through thousands of years by the tasting of fruits where sweetness usually means wholesome nutriment, it is fooled by these new compounds, which are much more sweet but not nutritious at all. Still they have been found convenient for diabetics who can not digest sugar and in a case of war when sugar costs too much.

The discovery of these synthetic sweets raises embarrassing questions in love and literature In courtship nothing less than superlatives will pass current and no self-respecting maiden will feel flattered to be called "honey" or told that she is "sweet as sugar" when she knows that there are similes far sweeter. Many of our girls are studying chemistry now-a-days and know too much to accept inferior substitutes in candy or compliments. Chemical names do not fit easily into verse, even when verse is most free and freaky. But doubtless a tabloid trade form will be devised, such as "saccharin," "dulcin" and "glucin." The compound that I mentioned first, the Japanese one, could be condensed to "peri" or "perilla." The former has already acquired poetical connotation through Moore's "Peri outside Paradise," but the latter would fit more neatly into valentine rimes, such as

The rose is red, the violet blue,
Perilla 's sweet, and so are you.

THE SCIENTIFIC MONTHLY

AUGUST, 1924

THE SCIENTIFIC WORK WHICH OUR GOVERNMENT IS CARRYING ON AND ITS INFLUENCE UPON THE NATION[1]

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In visualizing the picture of the scientific work of the federal government in its setting of service to the public, you will appreciate the necessity of our viewing the picture as a whole from a distance. It will be possible to indicate only the main theme and point out briefly some of the salient characteristics. This picture is heroic in size, grandiose in composition, harmoniously designed, vigorously drawn, possesses a wealth of color, and is executed with marvelous skill and painstaking care. As we approach it we shall see first in the foreground an indication of some of the semi-governmental activities, and then the broad, brightly lighted canvas on which is set forth, each in its proper relation to the others, the many-hued scientific activities of the government in which appear the portraits of not a few great men, and as we examine the dimmer background we may catch glimpses of less well-defined traits which will be better understood with the passage of time.

April 28 last marks a memorable date in the progress of science in the United States, for on that day was dedicated in Washington the building of the National Academy of Sciences and National Research Council, the two scientific organizations recognized by the federal government; the former founded by Congress in 1863 and the latter in 1917 by the President of the United States through the instrumentality of the academy. At this ceremony, the government was represented by the President who began his address by stating:

> If there be one thing in which America is preeminent, it is a disposition to follow the truth. It is this sentiment which characterizes the voyage of

[1] Commencement address, Case School of Applied Science, May 29, 1924.

Columbus. It was the moving impulse of those who were the leaders in the early settlement of our country, and has been followed in the great decisions of the nation through its history. Sometimes this has been represented by political action, sometimes by scientific achievements. On this occasion, the emphasis is on the side of science.

One of the duties of the academy is to act, when called upon, as scientific adviser to the government, and one of the important matters it has thus considered was a study of our forestry policy in 1896 resulting in constructive legislation, and it has again, at the request of the chief forester, decided at this April meeting to assist in formulating a plan for the conservation, restoration and utilization of our forest reserves, a problem of the utmost urgency to our national welfare, and one whose economic significance many of you as engineers will soon appreciate as relating to the supply and use of a basic material of your profession.

The Research Council was formed for the purpose of organizing and bringing to the aid of the government in war time the services of the scientific men of the country in the solution of the many intricate problems involving applications of science to warfare. The council was continued after the war for the purpose of initiating, correlating and stimulating research throughout the country. With its scientific divisions centered at Washington, and its division of engineering with headquarters in New York City, together with its many affiliations scattered over the land, the council is guiding a great part of our research work.

We are living in a world of associative effort in overcoming the difficult tasks that confront us in science and engineering, and you as young engineers will soon learn that few of the problems with which you will have to deal can be solved without consulting others from seemingly unrelated fields To-day, the engineer must be highly trained in some particular line of activity in which he may hope, with application and opportunity, to become in time an authority, but he constantly finds himself as he progresses upward in his profession calling for help from the physicist, the chemist, the biologist, the physician and many others in the solution of his engineering problems. This mutual dependence is well illustrated by the investigation recently completed by the National Research Council on the marine borer—an animal that destroys our seaboard structures—requiring the coordinated efforts of the engineer, the chemist and the biologist, both within and without the government service.

Another instance of such cooperative effort, involving advice as to the expenditure not merely of millions but of billions of dollars, is the committee of highway research instituted for the purpose of developing the best types of road construction and materials for the

country, and composed of engineers, technologists and scientists, representing the federal and state governments, as well as engineering societies and other interested national bodies. But perhaps the most striking illustration of the dependence of the engineer upon another profession was given in the construction of the greatest engineering work of modern times, the Panama Canal, which could hardly have been built, except at the cost of a terrible toll in lives, unless the medical men had first eliminated yellow fever from the isthmus.

Nearly a hundred years ago a British subject, James Smithson, left about a half million dollars to found at Washington under government supervision "an establishment for the increase and diffusion of knowledge among men." The Smithsonian Institution was established by Congress in 1846 "to assist men of science in making original researches, to publish them in a series of volumes, and to give a copy of them to every first-class library on the face of the earth." The Smithsonian now administers a great library, museums, zoological park and gallery of art, and carries out many explorations and other scientific activities, mainly related to American ethnology, anthropology and archeology.

A notable series of eminent men have headed this institution: Joseph Henry, famed for his electrical researches and his work in meteorology out of which came the weather bureau; S. F. Baird, founder of the fish commission, now the bureau of fisheries; Langley, the father of aeronautics, who also established the astro-physical laboratory, and Walcott, who is unexcelled in his chosen field of geology.

The federal government has long realized the need of scientific aid and associative effort in the solution of many problems of public interest, and by generous grants to the various executive departments has nurtured what the President has called "the opportunity for inspiring the people of America to insistence upon having the truth, and nothing but the truth, regarding everything that touches our life as a nation."

The oldest of the strictly governmental scientific services—which is also an engineering branch—is the Coast and Geodetic Survey established early in the last century under Hassler, a Swiss who brought with him our standards of length, weights and measures, in which establishment for many years, or until 1901, was invested the custody and development of our weights and measures. Out of this unit has sprung the greatest of our national laboratories, the Bureau of Standards, with its many scientific, technical and engineering activities, founded and developed for twenty-two years under the direction of S. W. Stratton.

You will recall how that giant among men, Leonardo, great in poetry, letters, painting, sculpture, architecture, science and technology, military and civil engineering, always began a painting by a most rigorous scientific study of the geometry and mechanics of his subject, supplemented by semi-finished studies. Similarly, viewed as a constructive work of art by the nation, it was fitting that there were first laid down the geometry and mechanics of the picture in the establishment of our weights, measures and geodetic base lines, and the precise astronomical work of the Naval Observatory and National Almanac Office, followed by a series of sketches as illustrated in the incomplete but manifold activities of the early Smithsonian Institution. From these foundations has sprung the scientific work of the government, as we see it to-day, as yet an unfinished picture, as again were so many of Leonardo's.

As agriculture is the most vital and extensive of our industries, on which all else may be said to depend for existence, so the development of scientific research in agricultural problems by the government has been cultivated more extensively than any other branch. Our picture thus becomes a landscape with appropriately grouped trees, plants and living creatures, clouds and soil, in which we recognize symbolized some of the fifteen great bureaus of the Department of Agriculture, such as forestry, plant industry, entomology, biological survey, soils, weather, public roads and animal industry. Here again, we are following the canvas of Leonardo who so skilfully blended his subject in a landscape in which appeared many manifestations of nature.

Our picture shows a continuous struggle against the inroads of disease in plants and animals, and for the maintenance of food supply and food standards; prevision against damage by the atmospheric elements, floods, forest fires and factory dust explosions; for improvement of roads, the preservation of bird life and the elimination of insect pests. The establishment of the Bureau of Fisheries gave the government an instrument for the scientific control and development of another of our great food-producing industries.

The government has not neglected in its scientific work questions relating to man himself, and consequently we have the public health service with its hygienic laboratory devoted to research in such matters as epidemics, social and occupational diseases.

Our mineral resources have in recent years become a matter of increasing concern to the federal government, their discovery, survey, development and conservation, as well as their application in industry and the arts. To meet these needs of the public there were established such units as the Geological Survey and the Bureau of Mines, which are the great governmental agencies for aiding the

mining industries of the country. There are in this field many fascinating problems, some of them of tremendous import to our industrial fabric. For example, our steel industry, by far the largest in the world, producing some 45,000,000 in a total of 71,000,000 tons yearly, is dependent on an adequate supply of manganese, most of which is imported. If our supply were cut off, what would we do? If we could not obtain enough manganese, our whole industrial organization would suffer unless a substitute method of manufacturing steel economically could be devised, or other materials developed. Here is a national problem of the first magnitude which may become acute, and perhaps some graduate of Case School may help to solve. There are other basic raw materials essential to modern industry not produced by our country, such as tin and rubber, the lack of which has stimulated governmental research to fill the gaps.

We do not ordinarily consider the military departments of War and Navy as productive scientific units of the government; but we may be sure that Leonardo, if he were to-day to compose a painting symbolizing the scientific work of the government, would give them a prominent place in his picture. It is but necessary to remind you of the strides made by these departments in radio communication during the war and since; the developments in aeronautical science, including aerodynamics and engine design; in explosives, which find their greatest application in civilian uses; and the rebirth of the science of acoustics, with its numerous applications in signalling. For many years the ordnance bureaus of the War and Navy departments have done more than any other agency in improving and maintaining the quality of special steels, out of which the metal materials of our automotive industry have grown. To the navy we owe our most marked advance in knowledge and application of steam, producing increasingly higher speed boats with wonderfully concentrated power units such as the modern turbine. Here it is possible to experiment on a large and comparative scale, as no private party can afford, on such matters as electric drive, internal combustion engines, and oil burners. Viewed in this light, the military departments, in addition to their prime function as national insurance and defense, become a very real asset in peace times for the advancement of science as related to industry.

One of the most recently established scientific branches of the government is the National Advisory Committee for Aeronautics, an interdepartmental board with civilian members from outside the service, which is charged with fundamental investigations relating to aeronautics. This committee maintains a laboratory at Langley Field near Norfolk, Virginia, and also supports scientific research at the Bureau of Standards and elsewhere.

I have left till the last the Bureau of Standards, realizing that if I had commenced with it, there would have been little room in our picture for the other scientific activities of the government. This bureau, with a population of some 800, of whom over 500 comprise the scientific and technical staff, is located on a commanding site some three miles from the center of Washington. It is splendidly housed in eleven permanent and several temporary buildings and possesses an unparalleled equipment for scientific research, the testing of many kinds of instruments and the investigation of numerous materials of engineering and technological processes.

The bureau, in addition to carrying out elaborate experimental work in the establishment and maintenance of standards relating to measurements of length, mass, capacity, time, electricity, optics, heat and other branches of physics and chemistry, is concerned also with the exact determination of many fundamental constants such as melting points, densities, specific heats, electrical and thermal conductivities, refractive indices, standard wave lengths, coefficients of expansion and of electrical resistance and a multitude of others of importance to science and industry. Investigations of a fundamental nature are also undertaken, such as problems in atomic physics, X-rays, radioactivity, the properties of steam and ammonia, the corrosion of metals, the ratio of the electrical units to each other, the constant of gravitation, the laws of aerodynamics, the theories of structures and the constitution of cements. Many of these basic problems are of a kind requiring very elaborate experimental arrangements and group cooperation over long periods of time, and are therefore particularly adapted to solution in a government laboratory. Instruments of all kinds from thermometers and chemical glassware to saccharimeters and wave meters are tested and the staff of the bureau have devised many new ones, with aeronautical instruments in the lead, and improved others. New materials are studied to determine their properties and availability for use in many fields of industry.

In addition to its purely scientific work, the bureau is also actively engaged in many technological lines such as metallurgy, ceramics, including optical glass, which the bureau manufactures, leather and rubber, textiles, paper and the materials of engineering. These investigations are planned largely with the help of advisory committees representing industry. A great deal of effort is spent in improving standards of quality of materials of technological and engineering importance; determining standards of performance of machines and devices such as automotive engines and elevator interlocks; and developing standards of practice, as illustrated by safety and service codes for industry and public utilities. Much of this

work leads to the formulation of purchase and operating specifications for use not only by the government but also by states and municipalities as well as in commercial transactions and industrial operations.

The bureau may also be said to be the consulting, research and testing laboratory in physics, chemistry, technology and many branches of engineering for the United States government. With the public, as represented mainly by manufacturers, engineering bodies, state and municipal authorities, the bureau has widespread, close and cordial relations. Inquiries for information requiring written replies and requests for services average over 300 a day, so that in addition to their laboratory work the staff of the bureau carries on a heavy, highly specialized correspondence.

The scientific output of the Bureau of Standards, as of the other government departments, is made available in publications distributed principally by the superintendent of documents.

And now we have completed as comprehensive a view as the time permits of this picture of the scientific work of the government. I trust you have found the picture a true one, an inspiring one. Its truth some of you, perhaps all of you, may have occasion to verify. One can not live in its atmosphere without becoming enthused with its uplifting qualities. The more often one contemplates and studies its details, the more one becomes impressed with its high ideal representing accomplishment, sincerity, beauty and truth. It is not a picture set apart in an inaccessible gallery, but is a very part, perhaps the most highly developed, responsive and vital part, of the life of the nation.

ASTRONOMICAL OBSERVATORIES IN THE UNITED STATES PRIOR TO 1848

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AN early American astronomical observatory may be defined as a tube with an eye at one end and a star at the other. Such observatories played an important part during the days of discovery, exploration and settlement.

The successful outcome of the voyage of Columbus depended upon observations of the stars, as attested by a leaf from his journal.[1] "Monday, 17th of September [1492]. The pilots observed the north point and found that the needles turned a full point to the west of north. So the mariners were alarmed and dejected." Columbus succeeded in allaying the fears of the pilots and the sailors by an ingenious, though specious, explanation based upon the motion of the heavenly bodies. Thus he was able to hold his crew, as well as his course, by an appeal to the stars.

Scientific "discouverers," equipped with mathematical and astronomical instruments, accompanied the voyages of some of the exploring and colonizing parties. Sir Thomas Hariot, the first English man of science to visit the New World, joined the second expedition to Virginia sent out by Sir Walter Raleigh, in 1585. His equipment and its effect upon the natives are given in his own words:[2]

> Most things they saw with us, as mathematical instruments, sea compasses, the virtue of the loadstone in drawing iron, a perspective glass whereby was shewed many strange sights, burning glasses, wildfire works, guns, books, writing and reading, spring clocks that seem to go of themselves, and many other things that we had, were so strange unto them and so far exceeded their capacities to comprehend the reason and means how they should be made and done, that they thought they were rather the works of gods than of men, or at the leastwise they had been given and taught us by the gods.

Hariot did not describe his "perspective glass." As he also mentions burning glasses we conclude that he possessed lenses. About twenty-five years later he was contemporary with Galileo in the telescopic observation of celestial objects.

Stars were observed during inland trips to direct the course

[1] The Journal of Christopher Columbus (The Hakluyt Society), 24, 1893.

[2] Narrative of the First English Plantation of Virginia (1588), Quaritch Reproduction, 39, 1893.

through the wilderness of the New World. The following letter[3] from James Alexander to Cadwallader Colden illustrates the practice.

Swartwoot's at Mackackemack
June 27th, 1719.

D Doctor

Our Luck was so good in a passage That on Tuesday after I Left you we got to Esopus where we Staid till Thursday dureing which time we observed Lucida Aquile in which observation

	fiducial Edge cutt	34°	37′	
	Plummett Cut	°	52′	
	Z Distance	33°	45′	
Hevelin's Declin: Wt	allowance for 58½ years	8°	10′	21″
		41	55	21

on Thursday we Set out from Esopus towards Mackackemack where yesterday we arrived all Safe and Sound and this morning we observed Lucida Aquile in which plummet cut 95° 49′ 30″ fid Edge 62° 35′ 30″ which makes us guess we are 15½′ to the Southward of our Latitude.

Astronomical observations for their own sake, for the love of science, also began in America at an early date. One of the earliest colonial observers to receive recognition abroad was Thomas Brattle, of Boston. "Baily,[4] in his supplement to the account of Flamsteed, states, that 'Mr. Thomas Brattle, of Boston in New England, is the annonymous person alluded to by Newton, in his Principia, as having made such good observations of the comet of 1680.'" Several of his observations are preserved in the Transactions of the Royal Society of London. On June 12, 1694, he observed an eclipse of the sun at Cambridge, four miles from Boston, New England. The eclipse observations[5] were preceded and followed by taking altitudes of the sun "to rectify the watch." The time of the beginning of the eclipse and the attainment of digits 1, 3, 4, 5, 6, 8, 9, 9½, 10 and 10½ (evidently on the basis of 12) were recorded, also the time of the corresponding decrease and of the end of the eclipse. Final results are given to the nearest minute of time as follows:

Began at	9h	14′	Mane
Ended	0	38	P. M.
Lasting in all	3	24	

In the calculation the latitude of Boston was allowed to be 42° 25′.

[3] Cadwallader Colden Papers. The New York Historical Society collection, 1917, Vol. I, 99, 1918.

[4] Quincy, "History of Harvard University," Vol. I, 412, 1860.

[5] Benjamin Motte, "Philosophical Transactions Abridged," Vol. I, 264, 1721.

Brattle's observations of lunar eclipses in 1700, 1703 and 1704 are also published. An item of the first is interesting: "6^h 42¼′. The shadow near an inch from Palus Maraeotis, Mons Horminius and Mons Hercules." His equipment is briefly mentioned. "My clock was set by my Ring-Dial about 9 a Clock in the Morning, as exactly as I could judge, and the observation was made with my 4½ Foot Telescope, with all four Glasses in it." Greater time accuracy was attempted at the eclipse of December 22, 1703. In addition to the use of the Ring-Dial, he observed both the rising and the setting of the sun and found that his clock went "very steadily and regularly." Then he adds: "But for the greater Certainty and Satisfaction, I took the Altitudes of the following stars with the Brass Quadrant with Telescope Sights out of my chamber window, the lowness whereof would not permit me to take them, when they were at all higher elevated." The three stars observed were, "In dextro humero Orionis, Procyon and Regulus." The range of the time corrections was 26 seconds. Observations on the lunar eclipse of December 11, 1704, compared with London gave a difference of longitude of 4^h 43^m.

Another colonial observer, whose work deserves more than passing mention, was Thomas Robie, who observed at Salem and at Cambridge. His earliest note preserved in the Philosophical Transactions refers to an earthquake. Astronomical observations followed.[6] On February 13, 1716–1717, he observed an immersion of the first satellite of Jupiter, at 10^h 48′ 17″; and on February 8, he observed an emersion at 8^h 7′ 30″; according to which the difference of longitude between Harvard College and Upminster is 4^h 45^m. His observation of the lunar eclipse of March 15, 1717, with "a 24-foot telescope," compared with the observations of Cassini and De la Hire, of Paris, made Cambridge, New England, 4^h 55^m 50^s west of Paris.[7]

Accurate latitude and longitude determination of other important centers was undertaken for the benefit of the geographers and surveyors. Contemporary with the work of Brattle and Robie in Boston, Douglas mentions that of Sir William Keith in Philadelphia and Cadwallader Colden in New York.

Preeminent among the early observations for astronomical value, rather than for geographical position, may be given those of Thomas Robie on the sun and Mercury. An unaddressed letter from Robie found among the Cadwallader Colden papers gives a full account of two observations.[8]

[6] Philosophical Transactions of the Royal Society of London (Abridged), Vol. VII, 530, 1809.

[7] Cadwallader Colden Papers, Vol. I, 166, 1918.

[8] Cadwallader Colden Papers, Vol. I, 159, 1918.

From Thomas Robie

(Unaddressed)

(Gov. William Burnet ?)

May it Please your Excellency

Sir

Hearing, by my very good Friend mr Jacob Wendal of Boston, of your Excellency's very great Knowledge in, & Affection to, Astronomy, & also of your great pleasure in receiving any Astronomical Observations, I venture at this time to cummunicate to you Two Observations wch I have made within about a Year past. The first is ye Observation of ye Sun's Eclipse in Nov. 1722, wch I made at Cambridge N. E. when I lived at ye College there, & it is thus, viz.

Nov. 27. 07h 27′ am:	I Saw ye Sun rise eclipsed, on its Supreme Vertex to ye South abt 4 Digits Tho some Persons on ye Top of ye New College Saw it 2 or 3 mins before. The true rising of ye Sun this morning was 7h 30′ Hence ye Refraction is abt 6 min. & So much I have often observed it here in ye Winter Time. From this time I could observe no more by reason of Clouds. But at—
8.30′. —	or there about ye Sun appeared again, & was I judg'd only by bear Occular Observation Eclipsed 6. Digts
8.55. 15″ —	The Sun was Eclipsed 4¾ Dig. nearest. & then ye Diameter of ye Sun was to ye Moon's as 1000 to 972 as well as I could Observe.
9.00. 15	When 4½ Dig. nearest wn hid, ye ○ Diameter was to ☽ as 1000 to 975.
9.19. 45	A little Spot in ye Sun, on its Eastern Limb emerged. The Spot was of this form °V°.
9.25. 45	I Saw ye Moon thro' a 24 feet Telescope go off ye Sun, & so ye Eclipse ended.
9.25. 45	Mr. Danforth in a darkned Room just by me saw ye Shadow go off ye Paper abt 30 degrs from ye Lower Vertex to ye East, & So did mr Appleton, ye Minister of Camb. in a darkned room a little distant from College, See ye Shadow leave ye Paper at
9.25. 20	

And as I am informed ye Center of ye Shaddow, past over Cape Cod. 2d The Second Observation is of mercury's being Seen in ye Sun, Oct. 29. last & it is thus, viz. Salem Oct. 29. 1723. Abt 11 in ye morning I saw ☿ thro' a 9 feet Telescope, advanc'd on ye ⊙ disk 6 or 8 min' of ye Sun's diamr It appear'd like a little black spot: abt 12.½ It was advanc'd near to ye Line Perpendicular to ye Ecliptic, & abt one I saw it & it had then Crost ye Axis, & abt ½ past 2. I saw it abt as far from ye Western Limb, as it was from ye Eastern in ye Morning wn I first saw it. By Several observations wch I made very carefully & distinctly, I judged yt there is an atmosphere round ☿ for round ye black spot wch was ☿ there was a dim light like a Halo, or wt ye Vulgar call a buss round ye ☽ when there are thin clouds. I took particular Notice of this because such Transits give ye Best opportunity to observe whether there is an

atmosphere round these Inferiour Plannets or no; & if I a'nt mistaken ☿ has one, & larger in proportion than ye ⊕. As for ye Eclipses ye next Year, 1724. Those yt will be vis. here I shall observe & if your Excellency shall do me ye honour of desiring my Obs. I shall readily obey You. There will be a Large Solar Eclipse in May next, Central & total in ye South west of England, as doubtless yr Excellency well knows, & so I only add yt it will be here abt 7 or 8 dig. as I remember I made it when I calculated it some years agoe. I have long wish'd for good Observations to be made at New York, but dispared, till I heard of yr Excellency's disposition, & now I hope ye Longitude between here & there will be established, wch will be a public Service.

I beg your Excellency's pardon for my Present Writing, & assure You I could not refuse doing it, from a desire I have of advancing my self in Astronomy, & hope your Excellency will be pleased to help me here in by your Communications, & yt You will be pleased always to account me,

Yours Excellency's
Most humble & Obedient Servant
THOMAS ROBIE.

Salem N. E. Nov. 9. 1723.

Professor John Winthrop, of Harvard, observed a transit of Mercury, April 27, 1740, with a 24-foot aerial telescope. His expedition to Newfoundland in 1761 to observe the transit of Venus was the first scientific expedition in this country provided by public expense. In 1769 he observed the transit of Venus at Cambridge.

Mason and Dixon arrived from England in 1763 to settle a boundary dispute between Pennsylvania and Maryland. Their first work in this country was to establish a surveying station and to determine its position with great care and accuracy. The building erected for this work, just south of the city of Philadelphia, was called Mason and Dixon's observatory. Extensive astronomical observations were made in 1763 and 1764, and the reduction of the data has been styled the first astronomical computation in America.

The greatest astronomical activity in America during the colonial period centered about the transit of Venus in 1769. The American Philosophical Society appointed three committees to make observations at Philadelphia, Norriton and Cape Henlopen. Temporary observatories were erected and instruments were obtained chiefly from London. The observations were successful and are given a prominent place in the first volume of the Transactions of the American Philosophical Society, and received favorable comment in England.

The work of David Rittenhouse deserves special consideration in this connection. His instrument shop on the Norriton farm was the center of astronomical activity before the time of the transit of Venus. Here he made the clocks and the instruments which he used at the time of the observations. He determined the position of the station and carried out the preliminary computations necessary for

the success of the undertaking. The accuracy of the observations at Norriton exceeded those of Dr. Thomas Ewing at Philadelphia, Owen Biddle at Cape Henlopen and those of Professor Winthrop previously mentioned at Harvard. Indeed, it seems that the Norriton results equalled the best obtained by Europeans. The calculations for Greenwich and Norriton, corrected for the spheroidal form of the earth, gave for the external contact a solar parallax of 8.″805. The present adopted value is 8.″80. Among the other observers were the English astronomers at Hudson's Bay, Madras and the South Sea Island, Otaheite, the French in California, the Russian at different points of Siberia and Russia, the Danish at the North Cape and the Swedish in Finland. Here we find American astronomical observations taking their place by the side of those made by Europeans, and we have not yet found the first real American astronomical observatory, a building erected and equipped with instruments designed for permanent observational use.

Following the success of the American observations of the transit of Venus an attempt was made to found an observatory in this country. Goode[9] says: "Had not the Revolution taken place, it would undoubtedly have resulted in the establishment of a well-equipped observatory in this country under the auspices of the home government." Dr. Ewing approached Lord North, the prime minister of England, and Mr. Maskelyne, the astronomer royal; and his project to establish an observatory in Philadelphia met with favor. The approach of the war made further cooperation impossible, as indicated in a letter from Maskelyne to Ewing in August, 1775:

> In the present unhappy situation of American affairs, I have not the least idea that anything can be done toward erecting an Observatory at Philadelphia, and therefore can not think it proper for me to take a part in any memorial you may think proper to lay before my Lord North at present. I do not mean, however, to discourage you from presenting a memorial from yourself. Were an observatory to be erected in that city, I do not know any person there more capable of taking care of it than yourself.

We believe there was a more capable man, David Rittenhouse. Before the transit of Venus had called forth special astronomical activity in the colonies, Rittenhouse, in his tool house on the Norriton farm, studied mathematics and astronomy, made clocks, and other mathematical and astronomical instruments, and began the accumulation of the equipment which played an important part on that occasion. This appears to be the reason for the selection of his site for a transit station. According to Goode,[10] "his observa-

[9] Annual Report of the Smithsonian Institution, 310, 1897.
[10] Report of the Smithsonian Institution, 412, 1897.

tory, built at Norriton in preparation of the transit of Venus in 1769, seems to have been the first in America." Soon after this event, Rittenhouse moved to Philadelphia, and his fellow-citizens, through the American Philosophical Society, petitioned the Philadelphia legislature, March 6, 1775, for an appropriation to enable them to erect an observatory and to grant Rittenhouse a salary as the "public astronomical observer." But the call to arms prevented the execution of the plan. Although Rittenhouse responded to public duty during the war, his astronomical zeal did not abate. On November 2, 1776, he observed a transit of Mercury; on January 9, 1777, an eclipse of the sun; on June 24, 1778, one week after the British evacuation of Philadelphia, he observed another solar eclipse.

The erection of his private observatory in Philadelphia, without aid from England or the Pennsylvania legislature, marks the establishment of the first astronomical observatory in this country deserving the name and receiving recognition. Goode says,[11] "When Washington became President . . . there were no scientific foundations within this repubic save the American Academy in Boston, and in the American Philosophical Society, Bartram's Botanic Garden, the private observatory of Rittenhouse, and Peal's Natural History Museum, Philadelphia." We do not know the exact date of the erection of his observatory. It was built on his "observatory lot" before he constructed his residence in Philadelphia in 1786. The observatory was "a small but pretty convenient octagonal building of brick in the garden adjacent to his dwelling" at the corner of Arch and (Delaware) Seventh streets. To adjust his transit instrument he invented the collimating telescope and he independently discovered the use of spider threads in the ocular. At the death of Rittenhouse, in 1796, the only observatory in the United States closed its doors.

Evidence of the existence of a short-lived observatory contemporary with Rittenhouse is given by his communication to the American Philosophical Society[12] containing observations made in 1789 at the University of William and Mary by the Reverend Dr. James Madison. "As the observatory in which the transit instrument had been formerly placed, was not, at this time, rebuilt, I was not enabled to attend to the going of the time-keeper, by means of such observations as I wished to have made." His equipment for observations included a sextant and an achromatic telescope magnifying about 60 times. He observed a lunar eclipse,

[11] "The origin of the national scientific and educational institutions of the United States." American Historical Association Papers, Vol. IV, Part 2, 310, 1890.

[12] Transactions of the American Philosophical Society, Vol. III, 150, 1793.

November 2, 1789, and a transit of Mercury, November 5, of the same year. Dr. Madison also includes observations of the transit of Mercury made by Professor Andrews with a reflector by Short with a magnifying power of 90. Lalande did not seem to know of the existence of this observatory, as he mentions only Rittenhouse's in the United States at that time.

Little astronomical work was done by the succeeding generation. The statesmen of the new republic, however, encouraged the development of science. Washington in his first message to Congress said: "Nor am I less persuaded that you will agree with me in opinion that there is nothing more deserving your patronage than the promotion of science and literature." Jefferson, who possessed marked scientific tendencies, contributed to the Proceedings of the American Philosophical Society and served a term as its president. These men, however, like Franklin and other master minds, called to more pressing political problems, gave their best efforts to the patriotic task of establishing the new republic on a secure foundation. Washington looked forward to the founding of a great national university. Barlow's "Prospectus of a national institution," in 1806, included plans for a national observatory. Hassler, in 1807, advocated the erection of two observatories at a great distance apart for the service of the Coast and Geodetic Survey. Instruments were obtained in 1816, one 6-foot Dolland achromatic telescope, two similar 5-foot instruments, two transits, two astronomical clocks, six chronometers, theodolites, compasses, reflecting circles, thermometers, etc. But Bowditch[13] laments as late as 1825: "It is to be regretted that no better use is made of them than to lock them up, after some have been spoiled, like articles of curiosity in a museum." In the meantime Congress was besieged by earnest advocates of the need of a national observatory. James Monroe, in 1812, when he was secretary of state, urged that deliberate body in vain. William Lambert, of Virginia, memorialized Congress frequently from 1810 to 1822; on the last occasion he presented an elaborate report on the need of an observatory. John Quincy Adams, in 1825, in his annual message to Congress, said: "It is with no feeling of pride, as an American, that the remark may be made that, on the comparatively small territorial surface of Europe there are existing upward of one hundred and thirty of these lighthouses of the skies; while throughout the whole American hemisphere there is not one." His proposition was ridiculed, and the expression, "lighthouse in the sky," became a common jest.

Airy, afterward the astronomer royal of England, in a report on the progress of astronomy, presented in 1832 to the British

[13] *North American Review*, April, 1825.

Association for the Advancement of Science, included a complete list of the observatories of the world and added: "I am not aware that there is any public observatory in America, though there are some able observers." In 1840, just eight years before the American Association for the Advancement of Science held its first meeting, a Boston correspondent of the London *Athenaeum*, commenting on the lack of observatories in the United States, said:[14] "True, nothing has yet been done, but then a good deal has been said"; I think he meant by Congress, for he adds:

> The facts are these: They have a small observatory in process of erection at Tuscaloosa, Alabama, for the use of the university in that place. Professor H.pkins, of Williams College, Massachusetts, has a little establishment of the sort, and this is about all in that state—all in New England! The only other establishment in the United States, known to me, is that in the Western Reserve College, Hudson, Ohio, under the charge of Professor Loomis. Nothing of the kind at our national seat of government or anywhere near it! Even Harvard University, "with all its antiquity, revenue, science, and renown," has thus far failed, though it appears that they are breaking ground at Cambridge; a house or houses having been purchased and fitted up, and one of our "savans" is already engaged in a series of magnetic and other observations.

Let us trace in detail how this small but prophetic beginning was made.

The spirit of Rittenhouse continued to inspire the Philadelphia observers, and his followers made many contributions to the American Philosophical Society. The desire to erect a public observatory at Philadelphia was cherished by many. In 1817, we find that the city granted to the society a building or part of a building for an observatory. Two pages of the Transactions[15] under the caption, "Philadelphia observatory," are devoted to a description of the building, the ordinance of the city council making the grant, and an appropriate resolution of sincere acknowledgments by the society. The building was located at the Center Square and was known as the Center Engine House. Only certain parts of the building were offered for the use of the society as an observatory, "to-wit, the south-east and north-west rooms in the basement story, together with the use of the passage between the said rooms; so much of the circular part of the said building as is above the basement story, and the roof of the said story." So far as we know, the said enactment produced no lasting results.

At Boston and at Harvard the scholarly successors of Winthrop carried on his scientific work. In 1780, Williams observed a solar eclipse and gave a good description of the phenomenon known

[14] *Athenaeum*, 555, 1840.

[15] Transactions of the American Philosophical Society, New Series, Vol. I, p. XVI, 1818.

as Bailey's beads 50 years before the time of Bailey. The organization of the American Academy of Arts and Sciences placed special emphasis upon practical knowledge. The labors of the astronomer were solicited; "particularly those observations and calculations which will serve to perfect the geography of the country, and improve navigation." It is not strange, therefore, to find that the astronomers were engaged by the government in the work of surveying, and the true spirit of observational work was retarded. Andrew Ellicott is perhaps the best example of a practical astronomer who served surveying. He contributed many astronomical papers to the learned societies, chiefly regarding observations made in connection with his boundary survey work. He also made some good observations of the comet of 1807 with a sextant of six-inch radius graduated by Ramsden. He sent some of his observations to Delambre, accompanying them with the explanation that they were made by "a self-taught astronomer, and the only practical one now in the United States." Such was the condition in 1816 that a friend of Comte in this country warned him against the purely practical spirit saying,[16] "If Lagrange were to come to the United States he could only earn his livelihood by turning surveyor." In connection with this kind of work, a so-called observatory was built on Capitol Hill in Washington about 1822 and was used by Lambert and Ellicott to determine the longitude of the place.

About the same time, 1823, W. C. Bond erected a small wooden building near his father's residence in Dorchester and equipped it with astronomical and meteorological instruments. Here systematic observations were made until Christmas day, 1839. His work also attracted the attention of the government and of the Harvard College Corporation.

The colleges of the country kept the spark of true astronomical fervor from complete extinction, and plans were in progress for the erection of observatories. At Harvard as early as 1805, Mr. John Lowell, then residing in Paris, consulted Delambre regarding observatories and procured written instructions which he transmitted to Professor Webber, one of the worthy occupants of the Hollis chair made prominent by the work of Winthrop. Ten years later, on May 10, 1815, it was voted by the college corporation "that the President (Dr. Kirkland), the Treasurer and Mr. Lowell, with Professor Farrar and Mr. Bowditch, be a committee to consider upon the subject of an Observatory." The services of W. C. Bond, who was just sailing for England, were solicited. He received a

[16] Cajori, "The Teaching and History of Mathematics in the United States," 94, 1890.

letter of instructions from Farrar, June 23, 1815, to obtain detailed information on observatories and equipment, when he was in Europe. Alas, the estimated cost of an establishment worthy of Harvard was too high and the project was again postponed. It was revived in 1822, and popular subscriptions began in 1823. J. Q. Adams, eloquent advocate of the need of a national observatory, pledged $1,000. Again the project failed.

After the time of Rittenhouse, up to the year 1830, notwithstanding the continued interest, nothing existed in the United States worthy of the name of an astronomical observatory, with the possible exception of Bond's at Dorchester. Suddenly the rapid rise of observatories began in America and soon the "lighthouses of the sky" dotted the hilltops along the Atlantic from Massachusetts to Carolina and penetrated inland as far as Ohio and Michigan.

According to Professor James L. Love,[17] North Carolina University deserves credit for erecting the first college observatory in this country. In 1824, Dr. Caldwell, the president of the university, was sent to Europe to buy books and apparatus. Among the instruments purchased in London were a meridian transit instrument and a zenith telescope made by Simms, a refracting telescope by Dolland, an astronomical clock by Molyneaux, a sextant by Wilkinson, a reflecting circle by Harris and a Hadley's quadrant. These instruments were used in the university buildings and on the roof of the president's house until 1831, when they were placed in an observatory which had just been built for them. F. P. Venable,[18] in his historical sketch, gives 1830 as the date of the erection of the building. The observatory was of brick and stone, about 20 feet square and 25 feet high. It had a well-constructed pier and was covered by a flat roof with a slit. Here instruction was given and observations were made by President Caldwell and Professors Elisha Mitchell and James Phillips. Shortly after the death of Caldwell in 1835, the instruments were removed on account of leakage in the roof. Bricks were carried away to use in building a kitchen for the new president. The observational records were lost. The instruments were quietly laid aside, and it is said that Sherman's soldiers found that the tube of the old telescope on a dusty shelf was selected by some of the professors as the safest hiding place for their watches and other valuable possessions.

At Yale University a more successful astronomical movement was in progress. In 1828, Mr. Sheldon Clark donated $1,200 for the purchase of a telescope, which arrived from Dolland, of London, in the year 1830. It had a 5″ object glass with a focal length of 10

[17] *The Nation*, August 16, 1888.

[18] *Sigma Xi Quarterly*, September, 1920.

feet. No building was provided, so it was placed in the tower of one of the college buildings. Without permanent mounting and lacking graduated circles, nevertheless, in the hands of Professors Olmstead and Loomis, it acquired a great reputation. The return of Halley's comet in 1835 was observed by them long before news arrived of its observation in Europe. The division of Biela's comet was first observed by Herrick and Bradley with the same instrument. Olmstead succeeded in creating great enthusiasm for astronomy and drew about him a strong group of men who assisted in ushering in the new era of astronomy in America. Loomis, Chauvenet, Stanley, Mason, Lyman and Twining owed their inspiration to him. His text-book on natural philosophy ran through no less than 100 editions. Although the astronomical work at Yale was very successful, no building was provided for an observatory within the period under discussion. Loomis,[19] in his excellent list of American observatories, gives first place to Yale, fixing the date at the time of the arrival of the Clark telescope in 1830.

We wish to give special emphasis to a structure entirely omitted by Loomis. Its astronomical nature was partly concealed by the name of "Depot of Charts and Instruments," which was established in 1830; but the building in which we are now interested was not erected until 1833. A boy of 15 entered the navy as midshipman. Of studious habits he advanced rapidly and soon received the grade of passed midshipman. Overhearing a remark by a member of Congress that "there is not an officer of the navy capable to conduct a scientific enterprise," he set to work to disprove it in his own case. When James M. Gilliss was ordered to Washington in 1836 as assistant to Lieutenant Hitchcock, in charge of the Depot of Charts and Instruments, he entered a small building 13′ x 14′ erected by Lieutenant Wilkes in 1833 in the vicinity of his own residence, about 1,200 ft. north of the Capitol. A 4″ transit borrowed from the Coast Survey was the chief instrument. Gilliss was set at work rating the chronometers and making sextant and circle observations. Soon he was placed in charge of this establishment and began his remarkable career. In the winter of 1837–38 he observed a series of moon transits and star occultations for longitude in connection with survey work. In 1838 the Wilkes exploring expedition started on its mission and Gilliss was ordered to remain in Washington and to continue observations. "From that time" (September, 1838), says Gilliss,[20] "till the return of the expedition in 1842, I observed every culmination of the moon, and

[19] Elias Loomis, "The Recent Progress of Astronomy," Third Edition, 1856. The author is greatly indebted to this work for much of the material that follows.

[20] Senate Report, No. 114, 28th Congress, 2nd session, 65.

every occultation visible at Washington, which occurred between two hours before sunset and two hours after sunrise. . . . The number of transits recorded exceeds 10,000, embracing the moon, planets and 1,100 stars. The average annual number of culminations of the moon observed was 110 and of lunar occultations about 20."

Gilliss's volume of astronomical observations was the first published in the United States. When Gould asked another astronomer whether the published observations were good and creditable to astronomy in America, he received the reply: "Yes; they are very good, too good for Gilliss's reputation. No man could have made such good ones." Professor Peirce tested the original records by the law of probabilities and vindicated both the truthfulness and the accuracy of the observer. Walker also tested the work and stated that he found only one astronomer, Argelander, whose transit observations manifested precision equal to those of Gilliss's. Not in consideration of the size of the building, nor the height of its dome, not by virtue of the cost of its instruments, nor to any superficial display, do we include Wilkes's observatory, as it was called; but from the standpoint of the results obtained by a faithful and unrewarded observer, we believe this building deserves an honorable mention among the early American observatories.

Williams College Observatory, Massachusetts, next claims our attention. Loomis calls this the first attempt to found a regular astronomical observatory in this country. In 1836, Professor Albert Hopkins erected a stone building, about 20′ by 48′, consisting of a central part and two wings. The central part was surmounted by a revolving dome 13′ in diameter under which was a Herschelian telescope of 10′ focal length mounted equatorially with graduation circles which read to minutes. A 3½ inch transit by Troughton and a compensation clock by Molineaux were also provided.

And now we begin our westward course. The next observatory was in connection with Western Reserve College, Hudson, Ohio. Professor Loomis went to Europe in 1836 to purchase instruments and returned the following year with an equatorial telescope by Simms with an aperture of four inches and 5½ feet focal length, and a 3-inch transit with graduated circle with microscopes reading single seconds. The clock by Molineaux had a mercurial pendulum. A convenient building, 16′ by 37′, was provided and the instruments were installed in 1838. Moon culminations for longitude, culminations of Polaris for latitude and star occultations formed the early observational program. Five comets were also observed for orbital determination.

The Philadelphia High School Observatory was erected at about the same time as Western Reserve. When the Central High School

was established, a sum of \$5,000 was set aside for an observatory. In 1838, a tower 45 feet high was erected in the rear of the school building. It is insulated 10 feet below the surface and is 12 feet in diameter. It is surmounted by a dome 18 feet in diameter and contains an equatorial telescope of 8 feet focal length and six inches aperture by Merz and Mahler of Munich, which is moved by clockwork. The erection of this observatory marked the beginning of the introduction of better equipment. Observations by Walker and Kendall attracted attention not only in this country but also in Europe. Their cometary observations were noteworthy, especially those of the great comet of 1843.

In 1839, there was erected an observatory at West Point. The large building was intended also for a library and contained philosophical apparatus. It had three towers for astronomy. The central tower was surmounted by a dome 27 feet in diameter. In 1840 Professor Bartlett visited European observatories and returned with instruments. The equatorial telescope, of 8 feet focal length and six-inch aperture, was made by Lerebour, of Paris. From this institution came Courtenay, Norton, Mitchel and Bartlett.

Soon after the erection of the observatory at West Point, the National Observatory was erected at Washington. The origin of this observatory may be traced to the needs of the naval service. The work of Gilliss had prepared the way in a more effective manner than the memorials of Lambert and the eloquent appeals of Adams. In 1842, he was instructed to prepare plans for a building. We can not go into detail to show how well the task was done. With some improvements suggested by European astronomers, the plans were adopted and Gilliss supervised the construction. Excellent equipment was provided and the institution was ready for work. On October 1, 1844, Lieutenant Matthew F. Maury, a young officer without scientific education or experience, and with small scientific pretensions, was appointed superintendent. Gilliss, who had a right to expect appointment, merely said, "It was hard, but an officer must obey orders and not find fault with them." An efficient staff was selected, however, among whom we find Walker, Hubbard, Coffin, Ferguson, Keith and Yarnall.

The Georgetown Observatory was begun in 1843, and finished in 1844. The central part was 30 feet square, with two wings, each 15′ x 27′. The chief instruments were an equatorial telescope with a 5″ lens by Simms, a 4½″ transit by Ertel and Son, of Munich, a 4″ meridian circle by Simms, and a sidereal clock by Molineaux.

And now we come to the Cincinnati Observatory, which excelled them all. This "temple of astronomical science," as it was proudly

and appropriately called by a citizen of Cincinnati,[21] was established by an organization of the people, by the people, and for the people, made possible by the magnetic leadership of Ormsby MacKnight Mitchel and the generosity of his fellow-citizens. Cincinnati may be justly proud of this achievement, the erection by the people of the first great astronomical observatory, not only in America, but in the whole world.

Mitchel was born at Morganfield, Union County, Kentucky, August 28, 1809, but the greater part of his life was spent in Ohio. His primary education was received at Lebanon, Ohio, and at 13 he was a clerk in a country grocery store at Miami. At the age of 16 he was appointed to West Point and graduated in 1829, a classmate of Robert E. Lee and Joseph E. Johnson. Then followed a few years of checkered career. He was assistant professor of mathematics for two years, then he was assigned to military service at Fort Marion, St. Augustine, Florida. We next find him in Cincinnati, where he studied law and was admitted to the bar. He practiced law and was chief engineer of the Little Miami Railroad. And then he found his post, or rather the place found him. In 1834, at the early age of 25, he was appointed professor of mathematics, philosophy and astronomy, in the newly established University of Cincinnati. In the winter of 1841–42 he accepted an invitation to deliver a course of lectures on astronomical subjects before the Society of Useful Knowledge. The beauty and sublimity of his style may be illustrated by a brief passage:[22]

> The starry heavens do not display their glistening constellations in the glare of day, while the rush and turmoil of business incapacitate man for the enjoyment of their solemn grandeur. It is in the stillness of the midnight hour, when all nature is hushed in repose, when the hum of the world's on-going is no longer heard, that the planets roll and shine, and the bright stars, trooping through the deep heavens, speak to the willing spirit that would learn their mysterious being.

His lectures were received with great enthusiasm, and at their close he announced his determination to secure for the people of Cincinnati an astronomical observatory equal in instrumental equipment with the best in the world. Miss Clerke, English historian of astronomy, gives great credit to Mitchel in her unique way. She says:

> The organization of astronomy in the United States of America was due to a strong wave of popular enthusiasm. In 1825, John Quincy Adams vainly urged upon Congress the foundation of a national observatory; but in 1843 the lectures on celestial phenomena of Ormsby MacKnight Mitchel stirred an im-

[21] Charles Cist, Sketches and Statistics of Cincinnati in 1851.
[22] "The Planetary and Stellar Worlds," 17, 1863.

pressionable audience to the pitch of providing him with the means of erecting at Cincinnati the first astronomical establishment worthy the name in that great country.

Mitchel organized the Cincinnati Astronomical Society, the first popular organization of its kind, with its heterogeneous membership, including literally doctor, lawyer, merchant, and we were about to add chief, rich man, poor man, beggar man, thief. He classified the membership under 67 professions and vocations, and adds: "Remainder unknown." He proposed to raise $7,500.00, in shares of $25 each, every subscriber to be a member and entitled to the privileges of the observatory. On November 9, 1843, the corner-stone of the observatory was laid by the venerable John Quincy Adams,[28] then 77 years of age. His eloquent oration on that occasion was one of the last public acts of his noble life. You may recall his rebuff by Congress nearly 20 years before. Here was his opportunity. He lamented the apathy of the nation toward the claims of astronomical science and congratulated the citizens of Cincinnati on the fact that their generosity and enthusiasm had at length wiped the reproach from the fair fame of their beloved country.

Here is where Mitchel's difficulties began. Only $3,000 out of the $9,500 pledged had been paid in. An additional sum of $6,500 was necessary to pay for the telescope alone, and Mitchel was appointed collector. Concerning this work, he says:

> A regular journal was kept of each day's work, noting the number of hours employed, the persons visited, those actually found, the sums collected, the promises to pay, the positive repudiations, the due bills taken, payable in cash and trade, and the day on which I was *requested to call again*. . . . By systematic perseverance at the end of some forty days the sum of $3,000 was paid over to the Treasurer, as the amount collected from old subscribers. Nearly two thousand dollars of due bills had been taken, payable in carpenter work, painting, dry-goods, boots and shoes, hats and caps, plastering, brick-laying, blacksmith work, paints and oils, groceries, pork barrels, flour, bacon and lard, hardware, iron, nails, etc., in short, in every variety of trade, material and workmanship.

$3,500 were yet required to pay for the telescope. The sum was raised by well-directed personal canvass for subscriptions among the more wealthy members. But where was the building to come from?

A magnificent site of four acres was donated by Nicholas Longworth, on the summit of Mt. Auburn, afterward named Mt.

[28] Jermain, G. Porter, "Historical Sketch of the Observatory of the University of Cincinnati, 5, 1923."

Adams, about five miles east of the city, at an elevation of 500 feet above the river. Mitchel went to work without a dollar in the treasury to construct the building. He hired laborers by the day, beginning with a force of two masons and one tender, all that he could afford to pay on Saturday night. The next week the force was doubled and soon increased to 50 men. He says: "Each Saturday night exhausted all my funds, but I commenced the next week in the full confidence that industry and perseverance would work out their legitimate results." The exorbitant cost of delivering material on the hill made it necessary to quarry limestone on the site, to build and fire a lime kiln, to open a sand pit, and to dam a ravine to get water. During all this time Mitchel continued his duties as professor in the university, often spending five hours a day in the classroom. Finally, the building was completed, a magnificent structure about 30′ by 80′.

At an earlier date (1842) Mitchel planned to visit Europe to purchase a telescope. He called upon President Tyler in the hope of securing letters of introduction to European sovereigns and savants; but received an indifferent response. John Quincy Adams, ex-president, gave him the desired credentials. He found an object glass of nearly 12 inches diameter and 17½ feet focal length, at the Frauenhofer Institute, Munich, made by Mertz and Mahler. It had been tested by Dr. Lamont and pronounced one of the best ever manufactured. This is the instrument for which he paid $9,437 in hard-earned cash. It arrived in February, 1845, and was soon ready for work. Equipped with eye-pieces to vary the magnifying power from 100 to 1,400, well-graduated declination and hour circles with verniers reading to 4 seconds and 2 seconds, respectively, and an excellent driving clock, it might seem as though Mitchel's troubles were at an end, excepting the trifling consideration that he had agreed to act as director for ten years without salary. He devoted much of his time to the remeasurement of Struve's double stars south of the equator. A number of interesting discoveries were made. Some stars previously marked as oblong were separated; others marked double were found to be triple, while his observations, combined with Struve's, demonstrated the fact that many of the stars are physical binaries.

But scarcely had Mitchel's observatory been completed when the college building burned and his salary as professor ceased. Unable to live on his salary as director, he again took to the lecture field and at one time to railroad engineering. But it was not for selfish motive or lack of astronomical zeal. His undaunted courage, unflagging energy and persistent perseverance mark him as one of astronomy's most loyal devotees, and one of the nation's most honored sons.

At the time our story ends in 1848, the Cincinnati observatory was playing an important part in the development of the chronographic method of recording time signals and in its application to the so-called American method of longitude determination.

We noted the postponed plans at Harvard to found an observatory and also mentioned the work of Bond in his private observatory at Dorchester.

> In October, 1839, the Harvard Corporation was informed that Mr. William Cranch Bond was engaged under an appointment and contract with the government of the United States, with a well-adapted apparatus, in a series of observations on meteorology, magnetism and moon-culminations, as also upon all the eclipses of the sun and moon and Jupiter's satellites, in connection with those which should be made by the officers of the expedition to the South Sea, commenced in 1838, under the authority of Congress, for the determination of longitude and other scientific purposes.[24]

It occurred to President Quincy, of Harvard, that, if Bond would transfer his instruments to Harvard and pursue his observations there, under the auspices of the university, it might facilitate the establishment of an observatory by the interest which his observations would arouse and by drawing the attention of citizens of Boston to the inadequacy of the means possessed by the university for difficult astronomical observations. Steps were taken to raise $3,000 for the purpose of altering a dwelling house owned by the college and known as Dana House, and adapting it for the use of Mr. Bond. An inventory of Harvard's apparatus at this time incudes an astronomical clock, unreliable; small transit, at one time loaned to Bowditch but returned because of little use; two reflecting telescopes, of two and three feet focal length and a quadrant. No more convenient place for using the instruments was available than an open field or a window which might accidentally open in the right direction. Bond brought to the Dana House a reflector of 30 inches focus, and an achromatic refractor of 40 inches focus, clocks, chronometers and magnetic apparatus. He was appointed director without salary, and yet the people did not respond.

The impulse towards awakening popular interest came from "the heavens itself." The unexpected appearance of the splendid comet of 1843 wrought the popular as well as the scientific mind into a state of excitement. It was a brilliant comet with a long train. The people of Boston naturally looked to the astronomers at Cambridge for information respecting its movements. The astronomers replied that they had no instruments. This announce-

[24] Quincy, "History of Harvard University," Vol. II, 391, 1860.

ment, together with the knowledge that good instruments were in existence in other parts of the United States, aroused the determination to supply the deficiency. Definite action was taken in March, 1843. The corporation of Harvard University purchased an excellent site of six and one half acres, for the erection of an observatory. Elevated 50 feet above the university campus, it commanded in every direction a clear horizon, without obstruction from trees, houses, smoke or other causes. Upon this site, known as Summer House Hill, the Sears Tower was erected for accommodation of the large telescope, with wings for the other instruments, and a residence for the director. The central tower is 32 feet square, built of brick, resting on a granite foundation, and is surmounted by a circular dome 30 feet in diameter. Here is mounted the 15-inch telescope, which arrived in 1847, another product of the Munich firm. It equalled, not only in size, but also in optical efficiency, the great refractor of the Russian national observatory at Pulkowa. These two "grand refractors" were the largest and most efficient in the world at the close of the period under discussion.

Immediate success followed the use of the large refractor. On September 17, 1848, Bond discovered Hyperion, the eighth satellite of Saturn, two days before it was seen by Lassell. This was the first addition to the solar system discovered in America. In 1850, it was followed by the discovery of Saturn's dusky ring. The work of the Bonds on solar and stellar photography and the resolution of nebulae with the Harvard apparatus would take us beyond the limits of our assignment.

Following the Cincinnati observatory, others were erected in rapid succession. Private individuals as well as colleges took part in the movement. Sharon observatory, a private establishment, was erected by Mr. John Jackson about seven miles west of Philadelphia. Its chief instrument was a 6 1/3″ refractor by Merz and Son, of Munich. Here we find American instrument makers beginning to play a part in the construction of equipment. The meridian circle was made by Young, of Philadelphia, only the object glass having been imported. The sidereal clock was made by Grokengiesser, of Philadelphia. In the upper part of the city of New York was the private observatory of Lewis M. Rutherford. It contained a 9″ refractor made in America by Henry Fitz, of New York. It was at this time also that Alvan Clark began his work, which soon made American objectives the most efficient in the world.

We can mention only by name the observatory of the University of Alabama, erected in 1843, although the telescope was not received until 1849, an 8″ by Simms; the Friends Observatory, Philadelphia,

built in 1846, provided with a Fitz 5″ objective; Amherst College Observatory, erected in 1847, where a 7¼″ Clark lens was later installed; Charleston Observatory, South Carolina, built by Professor Lewis R. Gibbes in his own garden; Dartmouth College Observatory, with an excellent 6″ equatorial by Mertz and Sons and other good equipment. Plans for observatories were in progress at a dozen other places.

By 1848, just 16 years after Airy made his statement concerning the lack of observatories in the United States, and just eight years after the London *Athenaeum* remarked that much had been said, but nothing had been done, we find about 20 observatories worthy of the name; and two of the number, the Cincinnati Observatory, representing the people, and the Harvard Observatory, representing the university, occupied a place among the best equipped observatories of the world. In 72 years after the birth of the republic it was ready to contribute its share in observational work and in astronomical discovery by the side of the nations of the earth in which astronomy had been cultivated from the dawn of civilization.

PARASITISM AMONG THE PROTOZOA

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(1) Animal Habitats and Types of Association among Protozoa

The earth offers various types of habitats for animals. The larger divisions usually recognized are (1) terrestrial, (2) fresh-water, (3) marine and (4) combinations of these. Most of the animals, however, that are of interest to medical zoologists have one characteristic in common—an intimate association with other organisms. Such animals do not belong in any of the above-named major habitats, but live upon or within the bodies of other animals and plants. Animals of this type have often been considered as living in the same habitats as their hosts, but it is obvious that their environment is radically different and that other types of habitats must be recognized to accommodate them. Various terms have been coined for the purpose of classifying the different types of association that exist among these organisms, but no single term is available that includes all of them. The word ectozoic has been employed for those that live on the outside of the body of the host, and the word entozoic for those that live within the body. The term parasitic usually serves to include both ectozoic and entozoic forms, and this usage may be considered correct when these organisms are discussed in popular language; but parasitism in its narrow sense involves a distinct disadvantage to one of the members of a pair of associated animals, *i.e.*, one animal, the parasite, lives on or in and at the expense of another animal, the host.

When species of Protozoa become associated with other animals or plants a large number of conditions may exist:

(1) The two members of the association may be mutually and equally beneficial.

(2) One member may secure a greater advantage than the other without either undergoing any disadvantage.

(3) One member may live more or less at the expense of the other without causing any injury to the body.

(4) One member may injure the body of the other but not enough to produce clinical symptoms unless present in large numbers.

(5) One member may be pathogenic to the other, *i.e.*, may give rise to a diseased condition. The disease produced may be mild and only a contributing cause of death or may be severe and the direct cause of death. Often one species of protozoan parasite may be lethal under certain circumstances and non-lethal under others.

The advantages gained by these associations are usually concerned with two of the most important fundamental requirements of all animals, namely, protection and food, and the character of the association is more largely influenced by the latter. The principal methods of nutrition exhibited by Protozoa are (1) holozoic, which implies the capture and ingestion of solid particles of food, (2) holophytic, which involves the elaboration of food by photosynthesis, as in plants, and (3) saprozoic, which means living on decomposing organic matter. Many Protozoa, both free-living and ectozoic or entozoic, employ several or all three of these methods of obtaining food. Thus an intestinal amoeba, like *Endamoeba histolytica,* may ingest red blood cells (Fig. 1, A) and other tissue elements, and may also absorb material through the surface of the body. This material may be decomposed organic matter or may be organic material prepared for digestion by the host. The term saprozoic, in the opinion of certain students, covers both the absorption of decomposed organic material and of digested substances, but is really limited by its etymology to the absorption of decomposed organic material and another term should be used for the absorption of digested substances. Frequently the term "parasitic nutrition" is employed, but this is bad usage, since parasites are not characterized by any definite method of nutrition but by one or a combination of the methods just described, that are common to free-living organisms as well.

Several of the types of associations that occur frequently among Protozoa are distinct enough so that definitions are possible; these are commensalism, symbiosis and parasitism. One partner may be a protozoon and the other a plant or both may be Protozoa.

Commensalism is applied to an association in which one partner is benefited whereas the other is neither injured nor benefited. The former is the commensal, the latter the host. How frequent such associations are among the Protozoa it is difficult to state, since it seems probable that if examined carefully enough the host will always be found to suffer some injurious effects from the association. For example, the flagellate, *Trichomonas* (Fig. 1, C), feeds chiefly on waste food products and bacteria within the intestines of its host, but it probably also absorbs through its body wall digested products of *use* to its host. When present in small numbers or when the host has an abundance of food the absorption of this material is probably of no importance to the host, but it may become a real menace when food is scarce and millions of the flagellates are present. The term "food-robber" has been used by Minchin to include species that feed on material in a more or less digested condition.

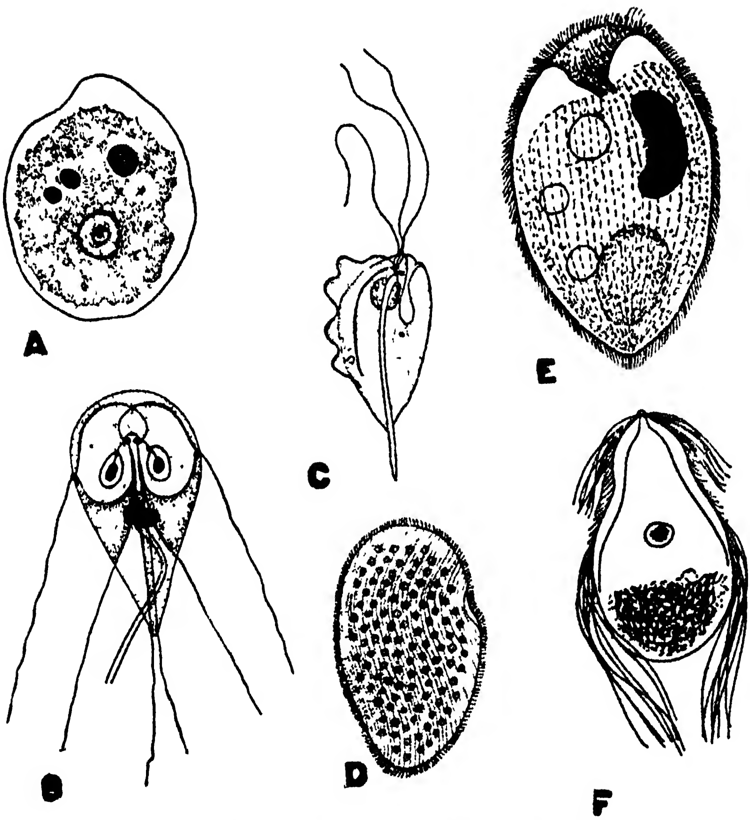

FIG. 1. PROTOZOA PARASITIC IN THE INTESTINE OF MAN AND LOWER ANIMALS

A. *Endamoeba histolytica,* the causative agent of amoebic dysentery in man. A nucleus and three red blood cells are visible.
B. *Giardia lamblia,* supposed to be a causative agent of flagellate diarrhea. The upper portion of the body is a sucking disc.
C. *Trichomanus hominis,* another supposed causative agent of flagellate diarrhea.
D. *Opalina ranarum,* a ciliate parasitic in the frog. No organelles are present for the ingestion of food.
E. *Balantidium coli,* a ciliate that causes dysentery in man.
F. *Trichonympha campanula,* a flagellate living in the digestive tract of termites. Wood particles are present in the posterior end.
(A, after Dobell; B, after Simon; C, after Faust; D, original; E, after Leuckart; F, after Kofoid and Swezy.)

Symbiosis is an association of two species of animals that benefits both parties. Sometimes the partnership is of such a nature that neither member can live without the other. An excellent example of this type has recently been described by Cleveland. This investigator finds that wood-eating termites starve to death on their usual diet of wood if they are deprived of their intestinal flagellates

(Fig. 1, F). Food in a partly digested condition defecated by the termites is fed to their offspring, thus passing on the infection from one generation to the next. The flagellates as well as the termites are enabled to continue in existence by this unique method of infection. In other cases, either partner can exist alone, but there is apparently an advantage to both in being associated. This is true of the association between certain Protozoa and algae. Thus *Paramecium bursaria* may live what we think of as the normal life of a free-living ciliate unless it chances to ingest certain algae. These spherical algae are at first contained in a regular food vacuole, but, instead of being digested, are soon brought into intimate contact with the protoplasm due to the disappearance of the liquid within the vacuole. They then divide and form a layer of symbiotic algae. Both the paramecia and the algae can live successfully alone but appear to be benefited by their symbiotic association.

As already stated, *parasitism* is popularly applied to any association in which one species lives on or within the body of another species. In this sense it includes many cases of commensalism and symbiosis. In a more restricted sense, however, it is simply an advanced type of commensalism in which the injury to the host is obvious. The terms ectozoic and entozoic, rather than the term parasitic, should be applied to species that live on the surface without injuring the host, or within the host but are not known to be injurious.

(2) Extent of Parasitism among the Protozoa

If we use the term parastism in its broadest sense, this condition exists in every large group of the Protozoa. One of the four classes into which the Protozoa are usually divided, the Sporozoa, contains nothing but parasitic species, and each of the other three classes numbers among its members many parasitic forms. It is impossible to state how the free-living and parasitic forms compare in number of species, but it seems safe to assert that there are at least as many species living on or within other animals as there are free-living species. This large number of parasitic species is correlated wth the fact of specificity of parasite and host, since frequently each species of host is parasitized by its own particular species of parasites. Furthermore, there are probably very few species of the higher animals that are not parasitized by more than one type of protozoon. A few examples will indicate the actual conditions.

Kofoid examined 5 species of Amphibia, 4 species of reptiles, and 6 species of mammals for intestinal flagellates, a total of 15 species. Flagellates were found in every species studied and in

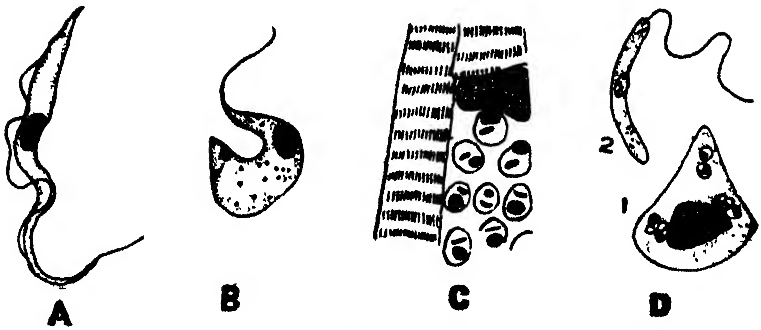

FIG. 2. PROTOZOA PARASITIC IN THE BLOOD OF MAN

A. *Trypanosoma gambiense*, the causative agent of African sleeping sickness.
B. *Trypanosoma cruzi*, the causative agent of Chagas' disease in South America. Stage occurring in the blood.
C. *T. cruzi*. Stage occurring in muscle.
D. *Leishmania donovani*, the causative agent of kala-azar. 1. Stage occurring in tissue. 2. Flagellate stage.
(A, after Castellani and Chalmers; B, C, originals; D, 1, after Brumpt; D, 2, after Row.)

all but 2 per cent. of the 329 individuals examined. But more than one species of intestinal flagellate was present in each host species; for example, the salamander, *Diemyctylus torosus*, was found to harbor 14 species of flagellates belonging to 10 genera. Furthermore, these animals may have been infected with blood-inhabiting flagellates as well as with intestinal flagellates; with Sporozoa of various types; with intestinal ciliates; and with intestinal amoebae.

In a number of cases one species of animal has been studied rather carefully for parasites. This is of course true of man and to a certain extent of domestic and lower animals. On the basis of such studies we can judge fairly well the abundance and number of species that really exist. In man, for example, we know five distinct species of amoebae, five species of flagellates, four species of coccidia, one ciliate, three species of malarial organisms, three species of trypanosomes, and three species of leishmanias—a total of 24 species of Protozoa. Besides these, are a large number of species that have been described but not yet definitely established.

There is no reason to believe that man is affiliated with more numerous species of parasites than are certain other vertebrates; a large number of species has been recorded from man because he has been more carefully studied.

(3) LOCATION OF PARASITIC PROTOZOA WITHIN THE HOST

The location of these organisms within the host may or may not be definite, but usually is. For example, one species of human

amoeba lives in the mouth, the others in the intestine, and different parts of the intestine may be the habitat of different species. One species, *Endamoeba histolytica* (Fig. 1, A), frequently finds its way into the liver and other parts of the body. The flagellates are mostly either intestinal or blood inhabitants, each species being rather definitely restricted to certain parts of the body. For example, *Giardia lamblia* (Fig. 1, B) is located in the duodenum, *Trichomonas hominis* (Fig. 1, C) in the large intestine, *Trypanosoma gambiense* (Fig. 2, A) in the blood, one stage of *Trypanosoma cruzi* (Fig. 2, B, C) in the blood, the other stage in the heart muscle, and *Leishmania donovani* (Fig. 2, D) in the tissues, particularly the spleen and liver. The coccidia are tissue parasites living in the epithelial cells lining the intestine or in the liver; the malarial organisms (Fig. 3) inhabit principally the blood cells, spleen, bone marrow, liver and brain, and the three species differ somewhat in their distribution within the body; segmenting stages of the estivo-autumnal parasite, for example, do not occur in the peripheral blood; the ciliate, *Balantidium coli* (Fig. 1, E) is restricted to the intestine although, unlike the flagellates, it may also become a tissue parasite.

When one studies the life-history of any of these protozoan parasites, it seems in many cases as though the parasite deliberately migrates to its definitive location, so perfectly is it adjusted to its complex environment. The sporozoite (Fig. 3, A) of the malarial organism seems to seek out a human red-cell; the gametocytes (Fig. 3, D, E) that later develop circulate about in the blood stream waiting to parasitize any anopheline mosquito that chances to bite its host; after fertilization (Fig. 3, F) has taken place the resultant ookinete (Fig. 3, G) recognizes the wall of the mosquito's stomach as an advantageous place for further growth and immediately creeps toward and penetrates its epithelial cells; and the sporozoites when they escape from the oocyst (Fig. 3, H, I) into which the ookinete develops make their way as rapidly as possible to the salivary glands where they lie in wait until they are given an opportunity to invade the blood stream of the human being the mosquito-host is biting. As a matter of fact, there are no such anthropomorphic qualities ascribable to parasitic Protozoa, the apparent selection of a satisfactory location at each stage in the life-cycle and the other activities of the organism having evolved through the operation of the same natural laws that are accountable for adaptations in all other living things.

(4) Specificity of Host

The character of the host is probably also to be explained not by selection on the part of the parasite but by the operation of natural

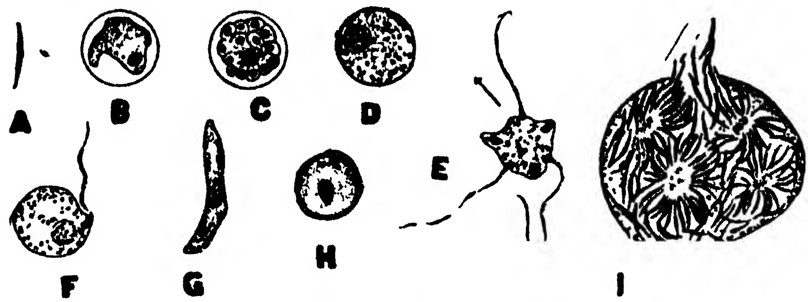

FIG. 3. STAGES IN THE LIFE-CYCLE OF THE HUMAN MALARIA PARASITE, *Plasmodium vivax*

A. Sporozoite ready to parasitize a red cell.
B. Trophozoite within a red cell.
C. Trophozoite undergoing reproduction by schizogony.
D. A female gametocyte.
E. A male gametocyte forming reproductive bodies (gametes).
F. Fertilization of a female gamete by a male gamete.
G. Ookinete.
H. Oocyst.
I. Ripe oocyst liberating sporozoites.

laws. The apparent selection of one species of host by one species of parasite is a very common occurrence among the protozoa. Perhaps the ectozoic forms are less particular than entozoic species. The ciliate, *Trichodina* (Fig. 4, B) for example, creeps about on the surface of *Hydra,* but appears to thrive equally well on tadpoles and planarians. In certain of the Suctoria all grades of host-selection have been noted: certain species attach themselves to almost any object either living or lifeless; others commonly are found attached to plants, such as *Discophrya cothurnata* to the leaves of *Lemna;* some prefer snails, others, Protozoa, water insects, hydroids or Crustacea; in some cases any part of the body of the host is apparently satisfactory, but frequently only one particular region is selected. For example, *Dendrocometes paradoxus* always is found attached to the branchial plates of *Gammarus.*

Entozoa, as a rule, seem to practice an even more rigid selection than ectozoa and not infrequently a genus will have a different species in each of a number of host-species. This is not always true, however, since in many cases a single species of parasite may occur in many species of hosts. An example of rigid specificity of host is afforded by the genus *Giardia* (Fig. 1, B.) Measurements and a careful study of the structure of giardias from various mammals indicate that constant differences of specific rank are present in different hosts. On the other hand, it has recently been shown by Becker that the flagellate, *Herpetomonas muscae-domesticae,* in-

habits the alimentary tract of at least six species of muscoid flies belonging to six different genera—an excellent example of nonspecificity of host.

(5) The Effects of a Parasitic Existence on the Parasite

The parasitic mode of existence has brought about modifications in structure and life-cycles that are worthy of the most careful study of any investigator. Many of these modifications are peculiar to particular genera or species, but others are more or less characteristic of entire groups of parasites and take the form of both simplification and complication. Degeneration of the organs of locomotion is a very common phenomenon among parasites; the members of the class Sporozoa are almost entirely devoid of the powers of locomotion, this function being taken over by the hosts which transport the parasite from place to place, and even transmit it from one host to another without any effort on the part of the parasite. The organs of nutrition are also often modified or lost; this probably does not occur as frequently in Protozoa as in the Metazoa. The Protozoa that are called "food-robbers" usually retain organelles for capturing and ingesting food particles—*Trichomonas hominis* (Fig. 1, C) is an example, with its well-developed flagella, cytostome and food vacuole mechanism. The normal condition for parasites, however, is life in an organic medium from which food is absorbed through the surface of the body; such an existence is often correlated with the absence of organelles for capturing and ingesting food particles; an example is the ciliate *Opalina* (Fig. 1, D) that occurs in the rectum of the frog. It is of course possible that the ancestors of *Opalina* may never have possessed these organelles, but it is probable that they were once present and have disappeared by a process of degeneration.

Some of the most complicated structural modifications have resulted from the necessity for maintaining some means of attachment to the host. *Trichodina* (Fig. 4, B) possesses a complicated circlet of rods and hooks that prevent it from being washed off from its host. *Giardia* (Fig. 1, B) has a sucking disc that serves the same function within the intestine of its host. Stalks, suckers and adhesive organs of various types are common among the Protozoa, evidently having evolved during the development of the parasitic habit.

The modifications mentioned thus far deal with the condition of the individual parasite. Others are concerned with the maintenance of the race. Chief among these is the increase in the powers of reproduction made necessary because of the very hazardous

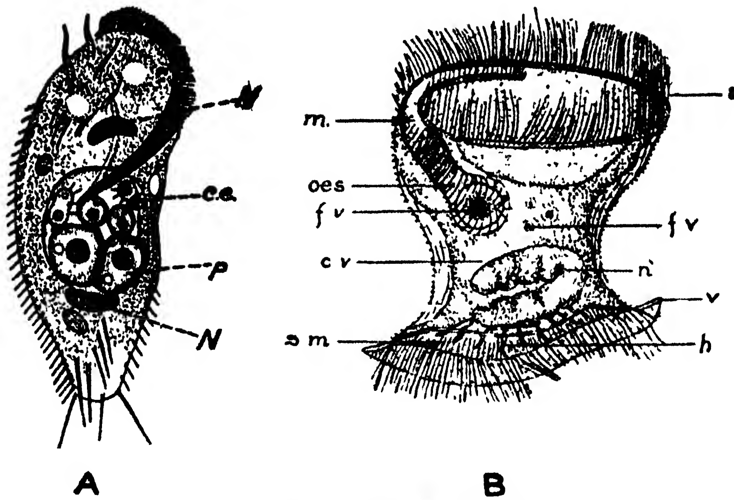

FIG. 4. CILIATE PROTOZOA

A. A protozoon parasitized by another protozoon. *P.*, parasite; *c. e.*, young parasite; *N*, nucleus. (After Stein.)

B. *Trichodina pediculus*, an ectoparasite on *Hydra*, tadpoles, etc.; *ad. c.*, adoral cilia; *c. v.*, contractile vacuole; *f. v.*, food vacuole; *h.*, hooks; *m.*, mouth; *n.*, macronucleus; *oes.*, oesophagus; *s. m.*, striated membrane; *v.*, velum. (After Clark.)

period during which the parasite leaves one host and becomes established within another. Simple binary division is usually all that is necessary to maintain the numbers of free-living Protozoa, but in many parasitic species certain types of sporulation (Fig. 3, C, I) have apparently evolved concurrently with the evolution of the parasitic habit, and these processes increase tenfold or more the possible number of offspring.

(6) LIFE CYCLES OF PARASITIC PROTOZOA

The principal stages in the life cycles of parasitic Protozoa that may be correlated with the parasitic habit are those that result in an increase in numbers of individuals; in changes made necessary for life within or upon other animals; in structural modifications for protection during the passage to new hosts; and in the adaptations for securing transmission from one host to another.

In the first place, it may be worth while to point out that we really know comparatively little about the life-cycles of either free-living or parasitic Protozoa; as a matter of fact we probably know more about the parasitic than about the free-living species. The elaborate life-cycles described and pictured in various text-books and original papers on protozoology should not be taken too seriously, however, since many of the details are obviously incorrect.

It is the custom to determine as many stages as possible by morphological methods from material collected more or less at random, and then fit them together into as orderly a cycle as possible. The result is only an approximation of the truth. Each cycle needs to be studied as a living continuous series of intergrading processes: a study that requires the use of experimental methods, and infinite industry and care. For those who wish to carry on investigations in the field of protozoology there are numberless problems begging to be solved—problems that require research ability of the highest type, and involve practical considerations as well as phenomena of the greatest biological significance. There are even serious gaps in our knowledge of the malarial parasites of man after forty years of continuous study by many of the most able investigators.

The increased powers of reproduction of parasitic Protozoa are brought about in various ways; the most common are the interpolation of schizogony and sporogony into the life cycle. A gregarine, *Monocystis*, parasitic in the earthworm, is an example of a form that increases by sporogony only. Each individual produces many gametes; these fuse in pairs; each pair develops into a spore; and within each spore eight sporozoites are formed. Each sporozoite grows into an individual ready to produce gametes again if proper conditions are encountered. This entire life-cycle is passed within a single host. Certain other parasitic Protozoa multiply both by sporogony and by schizogony and pass through the former in one host and the latter in a different species of host. The malarial parasite of man, *Plasmodium vivax*, multiplies rapidly within the blood of man by schizogony (Fig. 3, C); each parasite produces from 15 to 24 merozoites without first conjugating with another parasite. Eventually gametocytes (Fig. 3, D, E) are formed which can only complete their destiny when taken into the stomach of certain species of mosquitoes of the genus *Anopheles*. Sporogony (Fig. 3, H, I) occurs in the mosquito and results in the production of enormous numbers of sporozoites (Fig. 3, I) that are ready to start a new cycle of schizogony if inoculated into the blood stream of a susceptible human being.

Methods of escape from the host: Certain stages in the life-cycles of parasitic Protozoa seem to have evolved so as to enable the organisms to escape from one host and infect new hosts. Species, such as those inhabiting the intestine and other organs provided with ducts, have no difficulty in reaching the exterior, passing out of the host in excretory or secretory material. Thus the cysts (Fig. 5) of intestinal amoebae, flagellates and coccidia are passively carried out of the body in this way. When the parasites inhabit closed cavities such as the coelom or blood spaces, or live in the tissues,

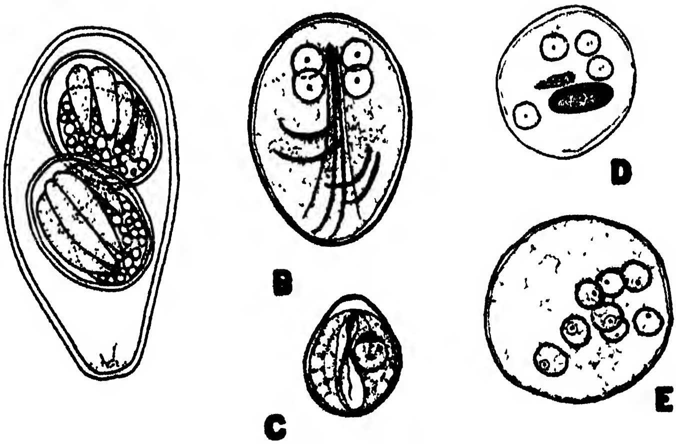

FIG. 5. SPORES AND CYSTS OF HUMAN PROTOZOA

A. Oocyst of a human coccidium, *Isospora hominis*, containing two spores, within each of which are four sporozoites.
B. Cyst of *Giardia lamblia*. (See Fig. 1. B.)
C. Cyst of *Chilomastix mesnili*, a human intestinal flagellate.
D. Cyst of *Endamoeba histolytica*. (See Fig. 1, A.)
E. Cyst of *Endamoeba coli*, a harmless amoeba living in man. (A, D, E, after Dobell; B, C, after Kofoid.)

greater difficulties are encountered and various methods of escape are employed. In some cases only the death of the host can possibly liberate the parasites; it is of advantage for this type of organism to cause the death of the host—a result that is actually accomplished by such tissue-infecting parasites as the Myxosporidia of fishes. The escape of the parasites and reinfection of new hosts may require the violent death of the host; this seems to be the case with the monocystis of the earthworm—the earthworm is eaten by birds through whose digestive tract the released spores pass unharmed; new hosts are infected by contamination of the food of the earthworm by the feces of the birds. The bird in this case can not be said to be parasitized. In other cases the host is eaten by another species of animal in which part of the life-cycle of the parasite takes place. Thus, in the case of the hemogregarine of the rat, the mite in whose body sporogony occurs is eaten by the rat in whose body the liberated sporozoites initiate schizogony.

Finally in some cases there seems to be no possible avenue of escape and we are forced to the conclusion that the parasites have entered a "blind alley" from which they never again emerge. The "blind alley" theory was proposed by Darling to account for the occurrence of Sarcosporidia (Fig. 6, D) in man, and is generally accepted at the present time.

Methods of entrance into new hosts: As all these cases indicate, escape is generally effected without any activity on the part of the parasite. In certain cases, however, the parasite actually migrates from one host and into another; this is true of *Trypanosoma equiperdum,* which causes dourine in horses. This species is supposed to make its way by its own activity through the mucous membrane of the host and during copulation of the host to penetrate the mucous membrane of another host.

A common method of entrance into new hosts is that of contamination. Races that are maintained in this way usually include in their life-cycles a resistant stage, which is most frequently a cyst or spore (Fig. 5) with a firm covering which impedes desiccation and prevents the entrance of deleterious substances. Such cysts and spores are widely scattered but do not undergo further development unless they reach a favorable environment. The chances of one of these cysts or spores reaching such an environment are so small that enormous numbers of them must be produced in order to prevent the race from dying out. This type of dissemination is the rule with intestinal amoebae, flagellates and coccidia, and among the Sporozoa in general. Among the vicissitudes encountered by cysts and sports of these species are (1) drying, (2) death due to the action of the bacterial mass in which they are embedded, and (3) death due probably to starvation in cysts and spores that reach an environment that is favorable in every way except as regards the presence of a new host. These cysts and spores must also be resistant to various excretions and secretions within the host, such as toxic substances in the fecal material before they leave the original host, and enzymes encountered within the anterior portion of the digestive tract of the new host, which makes it possible for them to reach their definitive habitat, the intestine, unharmed. It is even probable that certain of these enzymes are stimuli necessary before encystment can take place.

Certain species of intestinal protozoa, however, are not known to form spores, and their method of transmission is still in doubt. One notable case, however, that of *Trichomonas,* has recently been cleared up. Experiments have proved that the flagellate stage of the species, *Trichomonas muris,* that occurs in the rat, is able to pass unharmed through the mouth, esophagus, stomach and small intestine to the caecum, a distance of about 90 cm within half an hour and bring about an infection in the caecum. The human species, *Trichomonas hominis* (Fig. 1, C) therefore, which is known to be particularly resistant in the flagellate stage, probably brings about infections in new hosts by being ingested with the food.

Another large group of parasitic Protozoa are transmitted from host to host by inoculation by an insect or some other animal. This

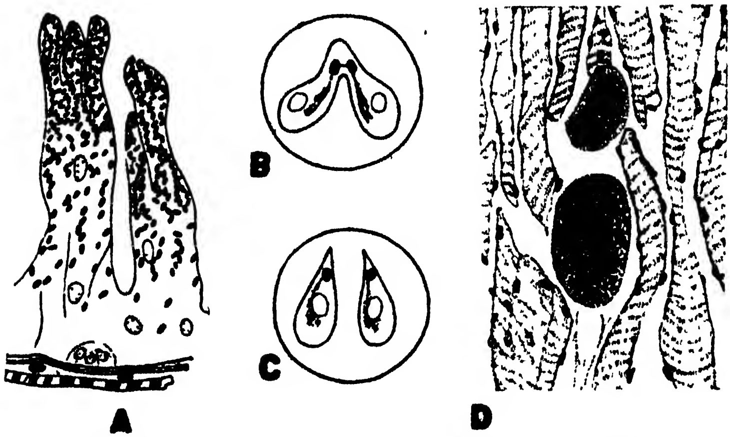

FIG. 6. PARASITIC PROTOZOA OF THE CLASS SPOROZOA

A. *Nosema apis* in wall of honeybee's stomach.
B. *Piroplasma canis* in a red blood cell of a dog.
C. *P. canis* after division.
D. Sarcosporidia in the muscle of man. (A, after White; B, C, after Nuttall; D, after Darling.)

is sometimes, but comparatively rarely, a mere mechanical transfer. Among the trypanosomes, most species ordinarily pass through part of their life-cycle in an invertebrate host, usually a fly, and a certain period must elapse between the ingestion of specimens by the fly and the development of infective stages within the fly, but rarely a fly, when feeding is interrupted, may immediately insert its proboscis into another animal and thus bring about an infection. In three species of trypanosomes this is the only known method of transmission. *Trypanosoma evansi,* the organism of surra in cattle and other domestic animals, and *Trypanosoma equinum,* the organism of mal-de-caderas in horses, are transferred mechanically by biting flies, and *Trypanosoma hippicum,* the organism of murrina in horses, is even distributed by a non-biting fly, the organism gaining entrance usually through harness wounds upon which the flies alight. It has recently been suggested that malarial organisms may be disseminated by mosquitoes by mechanical transfer, but there is no experimental proof of this as yet.

It is hopeless to attempt to describe all the different kinds of transmission by the inoculative method, but it is of interest to note that in most cases in which organisms are passed from one host to another without being subjected to an external environment no resistant spore stage is present. There may be spores, as in the malarial parasites, but these are not protected by a firm sporocyst.

The last type of infection of new hosts is often spoken of as

hereditary, inasmuch as the infective stage is transferred from the mother host to her offspring in the egg. The most notable instance of this sort was discovered by Pasteur in 1858, in the case of the microsporidian parasite, *Nosema bombycis* (Fig. 6, A), which causes silkworm-disease. Infection of silkworms with this protozoon may take place by the contaminative method, *i.e.*, by the ingestion by healthy worms of leaves soiled with feces containing spores, or by the hereditary method. In the latter case the ovaries of the infected moth are invaded by the parasites and the spores in the eggs remain dormant during embryonic development, becoming active in the caterpillar that hatches from the egg. Another notable example of hereditary transmission is that of the Texas fever parasite, *Piroplasma bigeminum* (Fig. 6, B, C), discovered by Smith and Kilborne in 1891, which infects the young of the cattle tick by way of the eggs. Hereditary transmission of malarial parasites was noted by Schaudinn but has not been confirmed; in fact, Mühlens has recently shown that the sporozoites of malaria penetrate almost every part of the body of the mosquito except the ovary.

(7) Origin and Evolution of Parasitism

We really know nothing definite about the origin and evolution of parasitism, since no one has ever observed a free-living species become parasitic, but there are many known facts that are of value in any attempt to work out lines of descent. (1) In the first place the parasitic habit must be more recently evolved than the free-living habit, since free-living forms must have existed before the parasites could obtain hosts on which to live. (2) Ectoparasites probably evolved before entoparasites, because the change from a free-living existence to that of ectoparasitism does not appear to be so difficult as to that of entoparasitism. (3) Inasmuch as there are free-living as well as parasitic species in every large group of Protozoa, it is evident that the parasitic habit has arisen independently in each of these groups and may therefore be considered of rather common occurrence during the course of evolution. (4) Most parasites belong to groups that are more primitive than their hosts, *i.e.*, are lower in the scale of life. Protozoa can not be parasitized by animals more primitive than themselves, but may be parasitized by plant organisms. Protozoa, however, are often parasitized by others of their kind, *e.g.*, free-living hypotrichous ciliates may be parasitized by Suctoria (Fig. 4, A). (5) As pointed out above certain ectoparasites are not limited to one species of host; others have been observed on only one species; and certain species are confined to a definite part of the body of the host. These are sup-

posed to be stages in the evolution of ectoparasitism. A species that is able to migrate from one species of host to another is probably in a more primitive stage of parasitism than one that is limited to one host, and the latter condition has probably originated from the former. The third type of ectoparasite mentioned represents a still further specialization, the parasite being limited to a single organ of the host. (6) The relations between ectoparasitism and entoparasitism, and commensalism and symbiosis furnish much material for speculation. Do commensalism and symbiosis lead to parasitism? Many students believe that they do. For example, a species that takes its meals in a state of mutualism with another species might develop into a food robber and from this into an actual parasite. Or, symbiotic relations might become disturbed and instead of a more or less mutual association one member might develop gradually into a pathogenic parasite. (7) Entoparasites may be limited to one species of host or may pass through part of their life cycles in one host and part in another. How did entoparasitism arise and which of the two conditions mentioned is the more primitive? Entoparasitism may have arisen from ectoparasitism, from commensalism or from symbiosis. If an entoparasite is restricted to one host species it probably adopted the parasitic habit within this species and is therefore no older phylogenetically than its host. Any changes that have taken place in the parasite have probably proceeded coincident with changes in its host. When an entoparasite occurs in several host species, the parasite is probably older than its hosts, having adapted itself to hosts that evolved after it became a parasite. (8) Parasites that have intermediate hosts have probably evolved from parasites with only one host species. This condition may have arisen because of the ability of the parasite to adapt itself to changed conditions, at first simply tolerating the second host but later actually establishing itself within it. The entrances of exogenous stages of parasites into other animals is very widespread in nature, and plenty of opportunity exists for parasitism to arise. In such cases as the hemogregarine that alternates between the rat and the mite, change of host is probably related to the predaceous habit, the second host feeding on the first host and in time becoming necessary for the complete life-cycle of the organism.

(8) Parasitism and the Geographical Distribution of Hosts

Finally, attention may be directed to the very interesting bearing of parasitism on the geographical distribution and genetic relationships of hosts. Von Jhering in 1902 was among the first to

discuss this problem in the case of parasitic worms. Zschokke in the following year compared in a similar way the distribution of tapeworms and marsupials, and the parasites of migratory fishes. Practically all parasites lend themselves to this method of attack. Kellogg (1905) has used it in his work on bird lice; Johnston has approached problems of evolution and zoogeography by the use of trematodes and cestodes, and Darling has studied the migrations of human races from data of hookworm distribution. The most important contribution to this subject resulting from the study of Protozoa is the recent work of Metcalf on the family Opalinidae (Fig. 1, D). This is too large a work to be disposed of in a few sentences, and those interested are therefore referred to the original report.

THE PHYSICAL BASIS OF DISEASE

I. CONGENITAL STRUCTURAL DEFECTS

By THE RESEARCH WORKER
STANFORD UNIVERSITY

It was the first day out from Chicago. The group in the smoking compartment of the Overland Limited had already discussed many topics of current interest. The morning papers, received at Omaha, contained an account of the illness of a prominent government official. There was a garbled description of his symptoms, with a polysyllabic bulletin from attending physicians.

"Those doctors are four-flushing," said the salesman from New York. "They haven't the least idea what's the matter with H———. Medicine is the easiest confidence game now worked on an unsuspecting public."

"How can they expect to know?" said the man from Boston. "They haven't the least idea what disease really is. So long as they deny the existence of God, and putter around with microscopes and test-tubes, they will never know."

"I am not sure that all cures are to be attributed to Deity," said the manufacturer from Pittsburgh. "We rented a house in the Adirondacks this summer. The owner left a lot of books. I don't go in for high-brow stuff as a rule, but some of these books interested me. Do you know, the Mohammedans, when they are sick, bind texts from the Koran about the sore part. And it cures them. Real authentic cures, no fake stuff. And South Sea Islanders offer sacrifices to idols, and are really cured. If you attribute these cures to Deity, you will have to admit that these people are just as right about Deity as we are. It can't be Deity. It's the effect of mind on the body. Get the wrong idea in your head and it makes you sick. Replace it with the right idea and you get well. Mental therapy. The rest of medicine is pure bunk."

"And look at the way they quarrel among themselves," said the real estate man from Denver. "Christian Scientists, osteops, chiropractors, homeopaths, and the big allopathic bunch, calling each other liars and each claiming to have the only true light. You don't find such a thing in business. Take an automobile. It breaks down. Tow it to any garage, and they repair it in about the same way. Some mechanics are more efficient than others,

but they all go about it in the same way. One man doesn't pray over your flivver, another put hot compresses on your radiator, and a third massage your rear tire, as they do in medicine. Four-flushing is correct."

"Our Denver friend is right," said a quiet individual in the corner. "There is great confusion in practical medicine. But physicians aren't responsible for this."

"You're evidently a doctor," said the lawyer from Spokane.

"No. Merely a witness for the defense. I am a worker in a laboratory for medical research."

"In other words, a paid apostle for the allopathic bunch."

"Hardly that. It is true, research workers furnish physicians, no matter to what school they belong, with the facts they use or are at liberty to use in practice. But the average research worker takes more pleasure in exposing the mistakes and incompetence of physicians, no matter to what school they belong, than he does in discovering new facts. We claim to be impartial, competent critics of the methods of all schools."

"You claim physicians aren't responsible for the confusion?" asked the lawyer.

"The responsibility rests with the general public. Any garage that treated all broken cars by massaging the rear tire would go bankrupt. The public has sufficient knowledge of automobiles to realize the absurdity of such a method. At some time, some car owner may possibly have thawed out his radiator with a hot-water bottle. He might possibly be induced to write a testimonial endorsing the hot-water bottle method. But no business man would spend hundreds of thousands of dollars in manufacturing a special automobile hot-water bottle, in the expectation of selling thousands of these bottles to car owners for the treatment of all automobile troubles. The public, however, liberally supports hundreds of equally absurd medical devices."

"It's good business," said the manufacturer, "to give the public what it wants."

"I doubt if it's a good business policy in medicine. Hundreds of thousands of preventable deaths are caused by this policy. The economic loss is millions of dollars annually. This is eventually a drain on all legitimate business."

"There are adequate laws governing medical fakes," said the lawyer.

"The laws are neither intelligent, adequate nor well enforced. They never will be till the general public has sufficient knowledge of fundamental facts to intelligently judge medical claims."

"A four year medical course for every individual," said the lawyer. "Some program!"

"No. About six hours of the right kind of instruction."

"You mean to say you can make me a competent judge in that time?"

"There are certain fundamental facts that can be mastered in a few hours."

So it came about that the manufacturer, the lawyer and the man from Boston adjourned to the lawyer's compartment, where the research worker presented the facts he considered of most importance.

"In the first place," said the research worker, "is there any one group of facts on which all physicians agree and which all practitioners must understand and use, no matter to what school of medicine they belong? There is such a group of facts in automobile repairing. Mechanics differ in methods, skill and efficiency in locating trouble and making repairs, but they all base their methods on an understanding of the physical nature of automobile trouble. A short circuit, a leaky valve, a cracked cylinder, deposits from inferior oil or gasoline. There is an equally fundamental group of facts in the human repair business."

"Suppose a physician doesn't accept these facts," said the lawyer.

"If a mechanic didn't believe in the existence of a short circuit, would you employ him to fix your car? His disbelief stamps him at once as incompetent. A short circuit is a fundamental mechanical fact. There are equally fundamental biological facts in human disease.

"Post-mortem examinations show that most diseases are caused by easily recognizable structural changes in the body. These are fundamental facts—not the subject of dispute. Elementary knowledge of the nature of these bodily changes in disease on the part of the general public would revolutionize practical medicine. I have selected facts of this kind to present to you.

"In presenting these facts I shall use the term 'disease' in a somewhat broader sense than generally employed. Your automobile may run smoothly and give full mileage, and yet be seriously defective. A cracked axle may markedly reduce your factor of safety. I shall use the term 'disease' to designate any alteration in the structure or function of any part of the human body, giving immediate symptoms, reducing efficiency, or reducing the factor of safety. These alterations all tend to shorten life. This is the usual technical meaning of the word 'disease'."

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"As our first group of diseases, let us select the various structural defects that may exist in the human body at the time of birth. Such defects may be produced in various ways. During the developmental period each organ of the body is grown independently, from an initial bud. The growth of each bud is governed by hereditary factors which are not necessarily the same as the hereditary factors governing other buds. Each bud is influenced by environmental factors, accelerating, retarding or modifying its growth. Many buds are located at a distance from their final places in the body, so that they must migrate during the developmental period.

"Fully 20 per cent. of all human embryos are discarded by nature before reaching full-term development. In many cases this is due to the death of the embryo from structural defects. At birth a considerable percentage of human young are found to be so grossly deformed as to be classed as monstrosities. Fifteen per cent. of all children die during the first month after birth. Autopsies show that half of these deaths are due to serious structural defects. Minor structural defects are probably present in most of us.

"These structural defects are of several types. A common type is congenital dwarfism of important organs or parts. You are familiar with this defect in external parts of the body, as shown by unusually small individuals, or individuals with an undersized arm, leg or head. Dwarfism is even more common in internal organs. A kidney the size of a pea is not uncommon; a lung may be entirely absent, or represented only by a bud the size of an olive; the stomach may be so rudimentary that for all practical purposes the esophagus joins directly on to the intestine. Individuals with such defects often reach adult life with no serious symptoms. There is a very generous factor of safety in the body."

"You use the term 'factor of safety'," said the manufacturer, "as though you could actually measure such a thing."

"Many of the factors of safety in the human body are subject to as accurate measurement as that used in most engineering work. I don't refer merely to such structures as bones and tendons, whose breaking strength can be determined in the same way one determines that of wood or steel; but to such organs as the heart, liver, lungs and kidneys. Take the kidneys, for example. Half, two thirds, three quarters, or the entire kidney tissue can be removed surgically from animals, and the effects on excretion determined. It is not till two thirds of the kidney tissue is thus removed that the remaining portion becomes inadequate for ordinary excretion.

This gives a factor of safety or reserve power in the kidney of three to one above ordinary needs.

"Dwarfism in certain organs, however, may give serious symptoms. Underdevelopment of the brain or of certain brain areas, for example, shows itself in reduced mental capacity and altered bodily control. Dwarfism of the thyroid gland produces mental inferiority."

"I have one criticism of medical men," said the lawyer. "They expect us to accept as gospel truth any statement they make, though in reality the statement may represent only a theory, often a damned poor theory on their part. That the little piece of meat in the neck you call the thyroid is responsible for mental inferiority strikes me as a statement of that kind."

"I am glad you mention this. I probably did not make it clear just what type of facts I am presenting. Medieval literature contains numerous descriptions of congenital idiots, cretins or semi-cretins—undersized individuals with infantile intellects. In medieval times a cretin was regarded as possessed of the devil, and was treated by religious methods. No cure by these methods, however, is recorded in all literature. As we shall see later, cretinism is not a type of disease that can successfully be treated by religio-therapy."

"Then you do admit there's something in religious treatment," said the lawyer.

"I fear I should be misunderstood if I admitted or denied it at this stage of our discussion.

"With the introduction of modern methods, autopsies were made on cretins. It was found that no matter what changes were present in other organs of the body, all cretins had one thing in common—abnormalities in the size or structure of the thyroid gland. Physicians therefore commenced to wonder whether or not there was a connection between an abnormal thyroid and cretinism. It was of course possible that the thyroid abnormality was a result of cretinism, or an unimportant accompaniment. There were physicians so bold, however, as to put forward the theory that the observed change in the thyroid gland was the cause of cretinism. This was of course pure theory, merely suggested by the statistical data.

"Assuming for the sake of argument that thyroid abnormality causes cretinism, the question arose as to how this was brought about. About the only way one can think of the thyroid gland as affecting mentality would be either (1) by destroying certain substances in the circulating blood that might injure the brain, or (2) by supplying the brain with necessary food substances or stimu-

lants. Assuming that the effect was by the latter method, physicians wondered whether or not the necessary brain foods or brain stimulants could be obtained from thyroid glands of lower animals. Physicians therefore administered extracts of thyroid glands of sheep to numerous cretins. A miracle was performed. The undersized, idiotic child often gained weight and mental vigor, and became practically a normal child within a few months.

"Study of thyroid function was now taken over by laboratory workers. It was found that conditions approaching cretinism could be produced on laboratory animals by the surgical removal of part of the thyroid gland. Chemists isolated an iodin compound from thyroid glands with which cretinism could be successfully treated. The relationship between thyroid insufficiency and cretinism is a proved biological fact. Every fact I shall present rests on an equally firm scientific basis."

"As our second type of structural defects, let us select the opposite condition—defects due to giantism or to duplication of important organs or parts. Giantism or duplication may affect the body as a whole, giving the excessively large individuals or double individuals occasionally born to normal parents; or it may affect any external part, giving rise to abnormally large or duplicated heads, hands or feet. Giantism or duplication is common in internal organs. A kidney, so large as to almost completely fill the abdomen, a second spleen, a third lung, are not at all rare at birth."

"I should think an unusually large kidney would be of advantage," said the manufacturer.

"The functions of the various organs are so evenly balanced that excessive growth or duplication of one part often leads to serious symptoms. Take the thyroid gland. This gland is occasionally congenitally enlarged or duplicated. We would expect one effect of this thyroid overgrowth would be the manufacture of excessive amounts of thyroid brain foods or brain stimulants. Extract from sheep thyroid administered in excessive doses or in too frequent doses produces marked intoxication, shown by palpitation of the heart, nervousness, insomnia, trembling and vomiting. These are the symptoms that are constantly or intermittently present in many individuals with congenitally enlarged or duplicated thyroid glands."

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"As our third type of structural defects, let us take deformities or distortions of important organs or parts, not necessarily asso-

ciated with abnormalities in size. Such deformities may be produced in several ways. One group, for example, is caused by a failure of union or fusion of early embryonic buds which normally fuse to form the adult organ or part. You are familiar with such deformities of the face. The early embryonic face, as you know, is represented by a series of buds which later unite and fuse to form the nose, lips and jaws. Failure to unite leaves open clefts or fissures at the time of birth, giving the various forms of hare-lip, cleft palate and unclosed passages to the trachea. Similarly, the brain and spinal cord are represented in early embryonic life as an unclosed depression or fold along the back. Imperfect fusion of the sides of this depression may leave various parts of the brain or spinal cord uncovered at the time of birth. Imperfect fusion of the abdominal walls may leave openings into the abdominal cavity.

"Incomplete fusion of embryonic structures also takes place in internal organs. The early embryonic heart, for example, is merely a U-shaped blood vessel. This gradually twists upon itself and fuses to form the later embryonic heart. Ingrowing buds in this twisted tube unite and fuse to form the partitions separating the heart chambers. These buds often fail to unite, leaving abnormal openings between the heart chambers."

"Such conditions must be rare," said the manufacturer.

"They are surprisingly common. Nearly 15 per cent. of all autopsies in certain hospitals show unclosed openings in the partitions between the right and left sides of the heart. The seriousness of this defect is at once evident. An unclosed opening in the partition between the two ventricles, for example, may allow blood to pass directly from the right side of the heart to the left side without first passing through the lungs. Unaerated or venous blood may be thus pumped out into the aorta to supply the needs of the body.

"Deformities or distortions of organs may also be produced by an abnormal union and fusion of structures which normally remain separate. Two or more fingers or toes may be grown together; the two eyes may be fused to form a single eye in the center of the forehead; the mouth opening may be absent. One of the most important fusions in internal organs is the absence of the opening between the stomach and intestines. Portions of the intestine may also be grown together to form solid cords. The external opening of the intestine may be absent. A fairly common example of fusion is found in the kidneys. The two embryonic kidneys occasionally unite to form a large single distorted organ."

"A single double-sized kidney wouldn't be a disadvantage," said the manufacturer.

"Not so far as the usual functions of the kidney are concerned. It is a disadvantage, however, in reducing one of the factors of safety in the body. One of our factors of safety is a duplication of organs or parts. Tuberculosis may destroy one kidney, for example, leaving the other kidney uninjured and capable of performing all necessary functions. Tuberculosis of a fused kidney, however, would tend to destroy the entire excreting mechanism."

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"Probably the most important group of structural defects are defects due to inferior structural material. The thyroid gland, for example, often shows this defect. Under the microscope the thyroid gland is seen to be composed of definite groups of special thyroid cells held in place by blood vessels and supporting tissues. A thyroid gland of normal size may be found microscopically to contain few, if any, thyroid cells. Its main bulk may be made up of an excessive amount of supporting tissue or of dilated blood vessels. Or, in place of the normal thyroid cells, there may be immature cells, or cells markedly shrunken, atypical or senile.

"The manufacture of the necessary brain foods or brain stimulants by the thyroid gland is carried out in the special thyroid cells. The other structures serve merely to mechanically support and nourish these cells. If the special cells are reduced in number, or are immature, or degenerate, the capacity of the gland to manufacture the necessary brain foods or brain stimulants is reduced. It is found, for example, that a certain percentage of cretins have thyroid glands of normal or even of increased size. Microscopically, however, these glands are always deficient in normal thyroid cells.

"Not all the inferiorities in structural material are so easily seen as this. Altered chemical composition, reduced growth potentiality, tendency to premature senility, may not show themselves microscopically. We have abundant evidence, however, that defects of this kind may be present at birth in the building materials of any organ or part of the body."

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"There are several minor types of structural defects we might consider. Among these are the curious misplacement of important organs, such as a liver or stomach located in the thorax, or a kidney deep in the pelvic cavity. Then there is the weird production of wholly abnormal structures in various parts of the body, such as a rounded mass containing bone, teeth and hair in the abdomen; or distorted sexual tissues growing from the roof of the mouth."

"It's sacrilege!" said the man from Boston. "The Supreme Power can't make such mistakes."

"Whether or not one considers it sacrilegious depends upon one's conception of the forces controlling embryonic development. The embryo, as you know, does not receive a single nerve or blood vessel from the mother at any stage of its development. It grows as an independent parasite, sucking up nourishment from the maternal tissue juices, in about the same way a plant sucks up nourishment from the ground. There are certain biologists so bold as to claim that the only forces governing embryonic growth are the ordinary physical and chemical forces of nature. Others believe that supernatural forces control or guide the entire processes of embryonic development. Still others conceive a spirit control to enter during a late stage of development, at the time of 'quickening.' Formal biological science has no quarrel with men who take any of these views. The subject is beyond the reach of experimental or observational science. It belongs to the realm of speculation, theory and faith."

"We are pulling into North Platte," said the manufacturer. "Let's get out and stretch our legs."

RESEARCH; THE MOTHER OF INDUSTRY[1]

By ARTHUR D. LITTLE

We are living in an age in which new impressions so crowd upon us that the miracle of yesterday becomes the commonplace of to-day. We fail to appreciate how rapidly our environment is changing, or how profoundly it has changed. In spite of the premature grayness of my residuary hair, you will, I am sure, be polite enough to agree that I am still a young man. I am, in fact, in the position of the little negro girl, who was asked how old she was. She said, "If you asks me how old I is, I'se five, but if you asks me how much fun I'se had, I'se most a hundred." When I review the industrial developments that have taken place within my recollection, I feel like the grandfather of Methuselah.

In "Mis' Nelly of New Orleans" Mrs. Fiske says, "I hate old friends, they always refer to 'that delightful Friday afternoon at the Centennial.'" You will forgive me for recalling that at the Centennial I saw, as a small boy, the first telephone and the first commercial arc light. May I also record that for ten successive days I ate Philadelphia ice cream. In 1884 I was trying to make 10 tons a day of sulphite pulp in the first mill on the continent. To-day we make 7,000 tons. When I opened a laboratory in Boston the street cars were drawn by horses, and I remember the clang of the first electric cars on Boylston Street and the consternation they caused among their equine competitors. From my window on Beacon Street two thousand bicycles an hour could be counted, where now more automobiles pass. I have seen the fish-tail burner supplanted by the Welsbach mantle and the incandescent electric lamp develop from carbon to tungsten filaments through to the white light of argon-filled bulbs. I remember the thrill with which I first saw an aeroplane sweep at dusk across the disc of the rising full moon and soar to invisibility above. Since then men have crossed the Atlantic in a single day and flown a mile in 13 seconds. Within a month the Shenandoah, filled with helium, has sailed majestically over the basin which faces my office window. That evening the Boston *Transcript* printed a description of the flight sent to its office by wireless from an aeroplane above the airship. I went with the crowd to hear Barnum's talking machine, cumbersome as a church organ, make guttural noises that bore an imagined

[1] Paper presented before a meeting of the Division of Engineering, National Research Council, University Club, New York, December 7, 1923.

resemblance to human speech, and later, in the Old South Church, heard Edison's phonograph, no bigger than a typewriter, reproduce a cornet solo by the passage of a needle over tin foil. Where the zoetrope excited the wonder of the children of my generation, the moving picture now bores thousands and entertains tens of millions. I still preserve the quill pen with which I often saw my grandfather write, and during my own first years in business all our letters were in longhand and copied in a press.

I well remember the incredulity which the announcement of the X-rays excited in some lay quarters, and the whole marvelous story of radium, which has led to altogether new conceptions of the structure of matter, is, of course, a tale of yesterday. It seems but a few short years since Hertz announced the discovery of long ethereal waves, which could be refracted and focussed by great prisms and lenses of pitch; yet during those years there has developed the whole wonderful system of wireless telegraphy and radio-telephony.

When I began the study of chemistry we were taught that there were certain permanent gases. They were called permanent because they could not be liquefied, but, almost before I had learned the lesson, Pictet and Cailletet had liquefied oxygen. There are now no permanent gases, and liquid air has become a commonplace of the laboratory and the raw material for great industries.

I was also taught that atmospheric air contained only oxygen, nitrogen, aqueous vapor and a small proportion of carbon dioxide. As even Mr. Bryan would admit that the human race has been immersed in air for at least six thousand years and might reasonably be assumed to know all there was to know about it, I accepted the instruction at its face value. Lord Rayleigh and Sir William Ramsay were less credulous and by the most brilliant, patient and refined research demonstrated the existence in the air we breathe of five hitherto unknown gases: argon, helium, neon, krypton and xenon. Even their names carry interest and suggestion. Argon, the lazy one, because it forms no compounds; helium, because the spectroscope had revealed its existence in the sun before its discovery on earth; neon, the new one; krypton, the hidden one; and xenon, the stranger. But already the lazy one has been put to work in incandescent lamp bulbs; helium, with nearly the lifting power of hydrogen and non-inflammable, has become the key to the safer navigation of the air by dirigibles; while neon tubes flash advertisements in shop windows and assist chauffeurs to locate engine troubles.

In 1898, Sir William Crookes, having in mind the inadequacy of the supply of nitrogenous fertilizers for the agricultural needs of our expanding population, and speaking as president of the

British Association for the Advancement of Science, said, "England, and all civilized nations, stand in deadly peril of not having enough to eat." That peril is now removed by the effective and spectacular processes, developed by chemists, for the production of such fertilizers by the fixation of nitrogen from atmospheric air.

My study of chemistry began with Eliot and Storer's Manual. Its copious index contains no reference either to catalysis or colloids. To-day catalysis has a copious literature of its own and is recognized as the determining factor in hundreds of reactions, on which are based new industrial methods for the production of such important and diverse materials as edible fats, ammonia, sulphuric acid, synthetic dyes and whole series of hydrocarbon derivatives. Colloid chemistry has become no less inclusive. It permeates such industries as tanning, artificial silk, rubber, smokeless powder, celluloid, photography and soap. It solves the problems of the makers of ceramic wares, shaving creams and shoe blacking.

The decade beginning with 1890 was notable for great industrial developments based upon research. In that year Hall brought out the aluminum process; in 1891 Acheson began the manufacture of carborundum and made available abrasives of a new order of efficiency; in 1892 Willson established the basis for the carbide, acetylene and cyanamid industries by his process for calcium carbide; in 1893 the Diesel engine was invented, Cross and Bevan communicated to me their discovery of viscose from which last year one American company made 22,000,000 pounds of artificial silk, and I demonstrated the Schultz processes for chrome tanning which have revolutionized the leather industry; in 1894 the automobile was developed; at about this time I was engaged in the investigation of the new electrolytic processes of Le Sueur and others for the manufacture of bleaching powder and alkali and was producing, by laboratory methods, cellulose acetate, the substance by which, during the world war, the wings of airplanes were protected; in 1895 Röntgen announced the X-rays; in 1896 Becquerel discovered radio-activity; in 1897 synthetic indigo, the product of German technical skill and financial courage, was placed upon the market and established still more firmly German control of the dyestuff markets of the world; in 1897 also Marconi sent a wireless message across Bristol Channel, while 1898 will be forever memorable for the discovery of radium.

As business men, you are accustomed to forecast tendencies by the trend of plotted curves. Let me assure you that the trend of the research curve is steeply upward. Research, which has paid these heavy dividends and countless others in one decade, needs only your recognition and support to enable it to pay still more heavily in the future. The vein is constantly widening, and the instru-

ments of research grow steadily more effective. Equally is it true that the means of reducing research results to practice are to-day incomparably better than they ever were before.

I would apologize for having given to this fragmentary and totally inadequate review so personal a tone were I not anxious to bring home to you the fact that all these great developments, so far-reaching in their influence upon industry, our mental outlook and our entire social structure, have taken place within the easy recollection of a man still on the job. Perhaps you recognized and turned to profit some of the opportunities that these developments afforded. Whether you did or not, it is worth your while to bear in mind that another procession is forming around the corner.

Three fundamental factors are involved in industry: capital, labor and the creative mind. The creative mind may function along the line of organization and management, or it may function along the line of research. In any progressive civilization industry is constantly pushing its outposts forward into the new territory wrested from the unknown by its advance guard, science. Now science is merely information, so classified and organized as to be used effectively and at once, and information, to quote General Phil Sheridan, is "the great essential of success." Advance information of the result of the Battle of Waterloo consolidated the Rothschild fortune. It is advance information, which may be of equal potential value, that research offers you.

Research to-day is extending the boundaries of every field of human activity and thought. It is to-day, more effectively than ever, directing industrial expansion into new channels and new territories. We are, for example, about to witness revolutionary changes in the preparation and use of fuel. Powdered coal has already established itself in engineering practice. Much progress has been made in low-temperature carbonization with higher recoveries of chemical values and the production of artificial anthracite. The conversion of coal to liquid hydrocarbons through hydrogenation has been demonstrated on the commercial scale in Germany, though the figures on the balance sheet are doubtless still in red. The gas industry is destined to a great expansion, which will involve radically new methods. The industrial use of gas has scarcely begun, yet in Baltimore, within the last six years, more gas has been consumed than during the preceding century. Systems for the complete gasification of coal have been developed, and there are serious proposals for great gas works at the mines and the distribution of industrial gas through high-pressure mains.

Steam pressures in central stations have reached 500 pounds, and pressures of 1,200 and even 1,500 pounds are cautiously being

tried. They present problems in the behavior and strength of steel at high temperatures in contact with water and gases that can only be solved by intensive research. The gas turbine presents other problems, which seem to be nearing a solution, but here, again, is more research required.

Decades of research have brought us to the point where we may soon expect oxygen, the supporter of combustion, to be as cheap by the ton as coal. That implies an impending revision of blast-furnace practice and of many operations in general metallurgy. It presents the possibility of the continuous gas producer and should raise the quality and heating power of industrial gas. It calls for new refractories.

Petroleum is about to be raised to a new and higher plane of usefulness and value, where it will serve as the starting point for the synthesis of whole series of organic compounds.

Biological chemistry is contributing new fermentation processes, which yield butyl and amyl alcohols, acetone, glycerine and fats, and in its alliance with medicine is conquering some of the most terrible scourges of the human race.

In 1922 Bohr published "The Theory of Spectra and Atomic Constitution." That, I submit, is seemingly far removed from industry and practical affairs. But Bohr's theory indicated that an unknown element should exist in zirconium-bearing minerals. In 1923 Coster and Hevesy, by means of X-ray analysis, found the element as predicted. It is named hafnium, in honor of Borh's city, Copenhagen. That you may the better appreciate the potentialities of this discovery let me add that hafnium is estimated to represent 1/100,000th of the earth's crust and to be, therefore, more plentiful than lead, tin and many other metals of commerce.

The French chemist, Dumas, writing to Pasteur concerning Lavoisier, the father of chemistry, said:

> The art of experimentation leads from the first to the last link of the chain, without hesitation and without a blank, making successive use of Reason, which suggests an alternative, and of Experience, which decides on it, until, starting from a faint glimmer, the full blaze of light is reached.

Our prosperity in the past has been largely based on cheap land and superabundant raw materials. To-day our civilization has developed such complexity that we can not hope to maintain our position except through the assistance which only science can afford. The laboratory has become a prime mover for the machinery of civilization, and the evidence that has been placed before you justifies the claim that there is a direct obligation upon industry to support research with the generosity of an enlightened self-interest, for research is the mother of industry.

THE RADIATION OF LIGHT[1]

By Professor HENDRIK ANTOON LORENTZ

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Before beginning my lecture I want to say in the first place that I feel it as a great honor to have been invited by this institution that has been made famous all over the world by the scientific men who worked in it, and in which, above all, there is so much that reminds us of Michael Faraday, the greatest discoverer in physical science perhaps who ever lived. Allow me in the second place to pay a tribute to the memory of Sir James Dewar, whose loss all physicists deeply deplore, thinking with great admiration of the talent with which he opened new paths of research. He has worthily continued the history of the Royal Institution, which forms an important chapter in the history of science itself.

One of the lessons which this history of science teaches us is surely this, that we must not too soon be satisfied with what we have achieved. The way of scientific progress is not a straight one which we can steadfastly pursue. We are continually seeking our course, now trying one path and then another, many times groping in the dark, and sometimes even retracing our steps. So it may happen that ideas which we thought could be abandoned once for all have again to be taken up and come to new life.

These remarks are well illustrated by the way in which at different times physicists have represented to themselves the way in which light is produced and radiated. You all know the two contending views, the emission theory or the corpuscular theory of light, developed by Newton, and the undulatory theory proposed by Huygens, perfected afterwards by Young and Fresnel, and newly shaped as the electromagnetic theory of light by Clerk Maxwell. I should now like to point out to you how these two theories, however widely different their principles may be, were interwoven in Newton's mind, and how it is well possible that they will be interwoven again in the physics of the future.

When one reads Newton's "Optics," one can not doubt that, when he speaks of a ray of light, he always thinks of a stream of small corpuscles emitted by a luminous body and moving along in straight lines, so long as they are not acted upon by some deflecting force. The phenomenon of diffraction, as we call it now, that had been discovered by Grimaldi and which Newton carefully examined

[1] Lecture before the Royal Institution of Great Britain, June 1, 1923.

experimentally, I mean the phenomenon that the shadow of a thin wire, for instance, is wider than it would be in the case of undisturbed rectilinear propagation, was attributed by Newton to certain repulsive forces with which the wire acts upon the rays of light when they pass along its surface at a very small distance.

The reflection and the refraction of light were likewise considered as due to forces which act upon the corpuscles of a ray when they come near the surface of separation of two media, like air and glass or water. Newton expressly states that the corpuscles must not be conceived to be reflected by the *individual* molecules of the body on which they impinge. If we could see the molecules, we should find the surface to be very rough, and it would be clear that their individual actions can hardly lead to a regular specular reflection. For this reason Newton supposes that the corpuscles of light are acted upon, not by the molecules separately, but by parts of the bodies containing a great number of them. This does not prevent us from supposing the actions in question to be appreciable at very small distances only. If they were sensible up to one ten thousandth of a millimeter, for instance, and if you had a corpuscle situated at half that distance from a polished plate of glass, then, since the structure of the glass is very fine grained with respect to the distance in question, the corpuscle would be acted upon by an immense number of molecules, and the discontinuities would not make themselves felt, so that it would be as if we had a perfectly smooth surface.

The forces of which I am speaking are comparable to those that were introduced much later by Laplace in the theory of capillarity. A corpuscle in the interior of a body will experience equal forces in all directions, so that there will be no resulting force and the particle continues its way with a constant velocity. It is only in a very thin layer, extending on both sides of the surface of separation, that there will be a resulting force, due to the unequal attractions, or perhaps repulsions, which the two media exert on the corpuscle. For reasons of symmetry the resulting force is perpendicular to the surface of separation, and therefore, whether the corpuscle be reflected into the first medium or allowed to continue its way in the second, the component of the velocity in the direction of the surface will remain unchanged. From this you can easily deduce the law of reflection. As to that of refraction, a simple diagram (Fig. 1) shows that, if the velocity along the surface A B is the same before and after the refraction, the sines of the angles which the ray makes with the normal N N, the angle of incidence i and angle of refraction r, will be inversely proportional to the velocities, say v_1 and v_2 with which the corpuscles move on the two sides of the surface, indeed, since the component of the velocity along the surface is v_1

sin i on one side, and v_2 sin r on the other, its constancy requires that

$$\sin i : \sin r = v_2 : v_1.$$

We shall therefore have found the well-known law of refraction, *viz.*, the constancy of the ratio between the two sines, if we suppose v_1 and v_2 to have definite values, whatever be the angle of incidence. Now, if the first medium is air, or rather the ether, we shall suppose v_1 to have a definite value, at least for rays of a particular color, on account of the way in which light is emitted. Once taking for

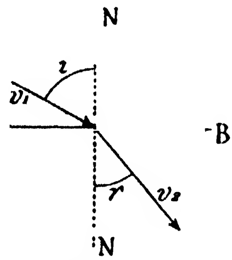

FIG. 1

granted this constancy of v_1, we can assure ourselves of that of v_2 by taking into account that the passage of a corpuscle from the interior of the first medium to the interior of the second will be accompanied by a definite change in the value of the potential energy, this value being in each medium the same for all positions of the corpuscle and whatever be its motion. By the law of conservation of energy the change in the kinetic energy of the corpuscle must be equal and opposite to that of the potential energy; thus, the difference $v_1^2 - v_2^2$ must be the same in all cases, and the constancy of v_2 follows from that of v_1.

I shall dwell no longer upon the further development of the corpuscular theory, but I must now point out to you how Newton also had the notion of vibrations, and even of waves, that are propagated in a medium. He was led to this by his experiments on the colors of thin plates, which we now attribute to interference, and which he examined very carefully for the case of the thin layer of air contained between a plane surface of glass and a surface that is slightly convex. Here we have the phenomenon generally known as Newton's rings. Suppose the light to be homogeneous and the incidence to be normal. Then, both in the reflected and in the transmitted light, you will see a number of alternating bright and dark rings, the dark rings in the transmitted light having the same diameters as the bright ones in the reflected light. This means of course, what is quite natural, that, at a thickness of the layer for which a great part of the light is reflected, only a small part is transmitted, and conversely.

The experiment shows that, of all the rays that enter at the front surface of the layer, some will be reflected at the back surface and others not, and that this depends on the thickness of the layer, the distance between the two surfaces. Further, that there is a certain periodicity in this. Now, since two rays, one of which is reflected at the back surface and the other not, must obviously be more or less different, Newton supposes that, after having passed the first surface, a ray or a corpuscle is in alternating states, *fits,* as he calls them, *of easy reflection and easy transmission.* But I think I had better give you this in his own words:

> What kind of action or disposition this is; whether it consists in a circulating or a vibrating motion of the ray, or of the medium, or something else, I do not here enquire. Those that are averse from assenting to any new discoveries, but such as they can explain by an hypothesis, may for the present suppose, that as stones by falling upon water put the water into an undulating motion, and all bodies by percussion excite vibrations in the air; so the rays of light, by impinging on any refracting or reflecting surface, excite vibrations in the refracting or reflecting medium or substance, and by exciting them agitate the solid parts, of the refracting or reflecting body, and by agitating them cause the body to grow warm or hot; that the vibrations thus excited are propagated in the refracting or reflecting medium or substance, much after the manner that vibrations are propagated in the air for causing sound, and move faster than the rays so as to overtake them; and that when any ray is in that part of the vibration which conspires with its motion, it easily breaks through a refracting surface, but when it is in the contrary part of the vibration which impedes its motion, it is easily reflected; and, by consequence, that every ray is successively disposed to be easily reflected, or easily transmitted, by every vibration which overtakes it. But whether this hypothesis be true or false I do not here consider. I content myself with the bare discovery, that the rays of light are by some cause or other alternately disposed to be reflected or refracted for many vicissitudes.

Let me add that, in order to account for the fact that light falling on a surface of glass is partially reflected and partially transmitted, Newton assumed that fits of easy transmission and easy reflection exist already in the incident rays before they reach the surface. He supposed *these* fits to have been impressed on the rays already in the act of emission itself; in fact he went so far as to imagine something like vibrations to go on in the source of light. Query VIII near the end of the book begins with the words: "Do not all fix'd bodies, when heated beyond a certain degree, emit light and shine; and is not this Emission perform'd by the vibrating motions of their parts?"

So there was much of vibratory or undulatory theory in Newton's ideas, though he seems never to have thought, as Huygens did, of the ray itself consisting in a propagation of waves. In Query XVII he again compares the ray of light falling on the surface of some substance to a stone thrown into stagnant water.

As you all know, the conclusion that the sines of the angles of incidence and refraction would be *inversely* proportional to the velocities of propagation became fatal to the corpuscular theory. The undulatory theory required that the two sines be *directly* proportional to the velocities of propagation, and when, about a century ago, the velocity of light in water could be measured, the result was in full agreement with the wave theory. I can briefly state the facts by saying that the index of refraction of water is about 4/3. The velocity of light in water ought therefore to be 3/4 of that in air according to the undulatory theory, and so it was found to be, but the corpuscular theory requires that it should be greater than the velocity in air, *viz.*, 4/3 times that velocity.

There now came a period during which the wave theory reigned supreme, until in these last ten or twenty years physicists were led to ideas, not exactly the same as Newton's but still more or less similar to the notions of the corpuscular theory.

The beginning of it was that, on the basis of the electromagnetic theory, a beam of light was recognized to possess a certain momentum, comparable to that of a moving ball. For the ball the momentum is given by the product $m\ v$ of the mass and the velocity, and when we attribute to the beam of light a certain momentum, say an amount Q of it, we simply mean to say that the beam has the same power of setting bodies in motion as a body would have, for which the product $m\ v$ has just that value Q.

The existence of momentum in a beam of light is shown by the pressure of radiation that was predicted by Clerk Maxwell, and observed and measured first by Lebedew and afterwards by E. F. Nichols and Hull. Let us consider this question for the case of a beam of light falling normally on a perfectly reflecting mirror, and let us compare the explanation by the undulatory theory, and the explanation that could be given by a follower of Newton, if there were one in these times. For the sake of simplicity I shall suppose that we hold the mirror in position by applying to it a certain force. If we can calculate that force we shall also know the pressure on the mirror, to which it is equal.

In the experiments the pressure has been compared to the energy which, in the beam of light, falls on the mirror in unit of time, the two quantities being proportional to each other. Now, according to both theories, the momentum which falls on the mirror has its direction reversed, and the ratio in question will be equal to that of twice the momentum of the light that reaches the surface during a certain time, to the energy of that same light. In the corpuscular theory this would be the ratio of $2\ m\ v$ to $\frac{1}{2}\ m\ v^2$, or $4/v$; thus, when c is the speed of light, $4/c$. On the undulatory theory the ratio

between the momentum and the energy of a beam is that of 1 to c, by which the result becomes $2/c$. You see that, for a beam of a given intensity, the pressure would be different in the two theories, in the undulatory theory half only of what it would be on the other view, so that here again we have a crucial experiment. The measurements have clearly decided in favor of the wave theory.

Our neo-Newtonian would have to own himself defeated by this, if he had been taught classical mechanics only, and had never heard of the changes that have been brought about by the theory of relativity. If he has studied this latter theory there is an escape for him; indeed, he can point out triumphantly that the values which relativity assigns to the momentum and the energy of any moving system are such that our last result $2/c$ holds in all cases. Only, this appeal to relativity would imply that the corpuscles become widely different from what they were originally thought to be. According to relativity dynamics a thing moving with the speed of light and having a finite mass, however small it may be, would have an infinite momentum and an infinite energy. Therefore, since the pressure has a finite magnitude, a corpuscle must be something with no mass m at all, but which, nevertheless, when moving with the velocity c, has a finite energy and momentum. By these assumptions the corpuscles become much like the so-called light quanta of modern theory, about which I should now like to say some words.

The word "quanta" is used by physicists in two different senses. In some cases we mean by it no more than definite amounts of energy of radiation, whose magnitude is proportional to the frequency n, or number of vibrations in unit of time, so that it can be represented by $h\ n$, where h is a constant. In this form the idea originated with Planck, who used it in the problems of heat radiation, and after whom the constant h is generally called. In Bohr's theory of spectral lines these minute amounts of energy play a fundamental and most important part; one of his assumptions being that light is not emitted in quantities of any magnitude, but in a greater or smaller number of full quanta that are radiated successively, one at a time.

It ought to be remarked that in this form the notion of quanta has nothing that is very startling or mysterious. If a tuning fork is made to vibrate by taps of a definite intensity, the fork being allowed to lose all its energy before it receives a new blow, we shall have emission of "sound quanta." We can imagine without difficulty that similarly in a source of light the energy is measured out in small but finite portions of a fixed magnitude.

However, this does not always suffice. There are phenomena from which, if we had to judge by them solely, we should certainly

infer that the energy of a quantum not only has a definite amount, *but also remains confined to a very small space.* In this way one has been led to the idea of "concentrated quanta," which may well be said to be Newton's corpuscles in a modernized form.

The phenomena to which I alluded are those of photoelectricity. When light of a suitable frequency is let fall on a plate of a properly chosen substance, electrons are set free, and it has been found that the energy of each of these electrons is equal to the quantum for the light which we use. This can be easily understood if the quanta are confined to small spaces, so that the electron can catch at once a whole quantum, whereas, when a quantum is spread out over a considerable extent, it is very difficult to see how an electron is to get hold of it. So the phenomena of photoelectricity seem to speak in favor of some corpuscular theory.

Let us, in order to make this clearer, suppose that the sensitive plate is first placed at a small distance from the source of light, and is then removed to a distance a hundred times as great, so that the intensity of the light or the total energy that falls on the plate in a certain time becomes 10,000 times less. Observation shows that the number of electrons liberated from the plate also becomes 10,000 times less, but that they are ejected with exactly the same velocity as before. This would be very natural if we could adopt some form of corpuscular theory, either the old or the modernized one. Then it would be clear that the number of corpuscles striking the plate has diminished in the ratio I mentioned, but that each individual corpuscle can do just what it did at the smaller distance, for the velocity has not been altered, and the corpuscle or the concentrated quantum has lost none of its properties.

On the contrary, when there are no concentrations, when, in spreading out, the energy becomes more and more dilute, we should expect that, at a certain distance, the light becomes too feeble ever to liberate an electron.

So it would seem that we really want concentrated quanta. But now, having recognized this, we have to face a very serious difficulty, a difficulty that hangs as a heavy cloud over this part of physics. Indeed, the existence of narrowly limited disturbances of equilibrium is absolutely irreconcilable with the principles of the undulatory theory as they are embodied, for instance, in Maxwell's equations of the electromagnetic field. According to these equations a disturbance of the state of the ether can never remain confined within a space of constant magnitude; around each point that is reached by the disturbance there is a propagation in all directions, and so there is always the tendency to a lateral expansion that becomes manifest in the phenomena of diffraction. It is true that,

when our openings are wide in comparison with the wave-length, we may have beams of light that are rather sharply defined over a certain length, but if we go far enough along the beam we shall ultimately notice an unlimited expansion. When, for instance, parallel rays are made to pass through an opening of one centimeter in diameter, we shall observe an illuminated circle of the same magnitude with a rather sharp border on a screen at a distance of some meters, but if the screen is removed to a distance of 100 kilometers, there will be a badly defined patch of light extending over something like half a meter. Or, again, take the case of a disturbance initially confined within a spherical space a centimeter in diameter. At some later instant it will be found in a shell of this thickness, bounded by two concentric spheres which both expand with the speed of light. By properly choosing the distribution of the disturbance in the initial sphere, you have it in your power to produce different distributions in the expanding shell, but you can never prevent the disturbance from ultimately occupying a very considerable part of the spherical wave.

One might object that these are mostly theoretical inferences and that we must never swear by a theory, not even by Maxwell's. Let me therefore conclude by pointing out that, so far as we can see now, the hypothesis of concentrated quanta is directly in contradiction with observed facts, *viz.*, with what is seen in the phenomena of interference.

You know that bright and dark interference fringes can never be produced by means of two different, mutually independent sources of light; we explain this by the want of all coherence between the vibrations in one source and those in the other. Now, the elementary acts of emission, in each of which a quantum is radiated, must certainly be incoherent; they may take place in different atoms, and there is not the least reason why there should be any connection between what goes on in one atom and in another. Hence, when we observe an interference phenomenon, *one* quantum taken by itself must be able to produce it, and this will enable us to draw some conclusions concerning the extension of a quantum in different directions.

In certain experiments made with highly homogeneous light, interference fringes have been observed, produced by rays whose paths differed by more than a million of wave-lengths. This means that there was a regular succession of more tnan a million of waves, and, since all these waves must be contained in one quantum, the length of a quantum in the direction of propagation must have been more than, say, 50 cm. That the lateral dimensions must be no less considerable is shown by the influence which the aperture of an

optical instrument has on the quality of the images, and consequently on the resolving power. Let L (Fig. 2) be the objective glass of a telescope, a "perfect" lens from the point of view of geometrical optics, so that, if there were no diffraction, the rays R coming from a distant star would converge exactly towards the focus F. In reality this can never be; on the plane V there will be an illuminated spot of a certain extent, and if we want to have this spot small, so that there is a sharply defined image of the star, we must use a large lens. As a matter of fact this is one of the advantages of the great modern telescopes.

Let us conceive the opening of the telescope to be divided into two parts, say of equal areas, a central circle L_1 and a ring L_2 around it. If, by means of a screen with a circular opening, we

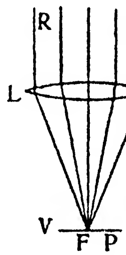

FIG. 2

reduce the aperture to the part L_1, the image of the star becomes less sharp; a point P at a small distance from F, which remains dark when the full aperture is used, may now be illuminated, the light disappearing again when the screen before the lens is removed. The explanation is, of course, that the vibrations which P receives from L_1 are counteracted by opposite ones coming from the part L_2. So, the fact that a large opening actually has the effect on the quality of the image which we expected from it, shows that there is interference between vibrations reaching the lens at different points of its surface. According to what we saw these vibrations must belong to one and the same quantum, and we may therefore conclude that the lateral extension of a quantum is comparable to the size of the objective.

The remarkable experiments by which Professor Michelson has been able to measure the diameter of some stars allow us to push the argument still farther. In his apparatus a beam carrying four mirrors, 1, 2, 3, 4, was placed in front of the opening of the telescope, the mirrors 2 and 3 occupying places within the opening, whereas 1 and 4 were outside the opening, on opposite sides of it. The mirrors were adjusted in such a way that two beams of rays coming from the star entered the instrument, the one being reflected

by the mirrors 1 and 2, the other by 4 and 3. The fact that under these circumstances interference fringes appear in the field of view proves that a quantum must reach from one of the outer mirrors to the other. The distance between these mirrors was no less than 6 meters.

The discrepancy between these estimates of the size of a quantum, according to which it would be too big to enter our eye, and, on the other hand, the notion that it is small enough to be captured by a single electron, is certainly very wide. Yet the laws of the two classes of phenomena about which we have reasoned, the phenomena of interference and those of photoelectricity, are so well established that there can be no real contradiction between what we deduce from one class and from the other; it must after all be possible to reconcile the different ideas. Here is an important problem for the physics of the next future. We can not help thinking that the solution will be found in some happy combination of extended waves and concentrated quanta, the waves being made responsible for interference and the quanta for photoelectricity.

THE ORIGIN, NATURE AND INFLUENCE OF RELATIVITY*

By Professor GEORGE D. BIRKHOFF

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VI. The Philosophical Influence of Relativity

It is the chief function of philosophy to furnish as wide and well-balanced a view as possible of nature and mind—those antipodal aspects of the universe between which reality lies. Advances in the physical and psychological sciences have always exerted a potent effect upon philosophic thought, and the reciprocal effect has been quite as noteworthy. For a mathematician like myself it is indeed a daring project to venture, by way of conclusion, into this speculative realm, and to attempt to evaluate the philosophical influence of the recent theory of nature called relativity.

By very definition, what is accidental is without especial interest for philosophy. From its earliest beginnings it has been directed towards that which has general significance in experience. Schools of philosophy fall into two classes: the first type takes its primary model in some generality of nature, and so may be called objectivistic; the second type begins with some generality of mind and may be called subjectivistic.

The penetration of nature with numerical relationships was doubtless noted very early by man. In truth, the most useful distinguishing mark of any class of objects is its number. Everywhere in nature, and also in mind, are classes and accordingly a rôle for number. Pythagoras and his school perceived that space and time were numerical in their essence. They conjectured too that number played a dominating part in other ways; the laws of the musical string and the motions of the stars and planets were sufficient indication to them that such was the case. The keynote of their various speculations was that the universe was arithmetical throughout.

Plato was the first great subjectivistic philosopher. He took as primary the model of abstract mathematical truth. His conception of the occupation of the Deity was that of continual geometrizing. It was his great advance to have appreciated fully that there were other ideas, not reducible to number or form, and yet having the same degree of living reality; chief among them were such social ideas as the good and the beautiful. Material fact was held by him to be less real than these ideas themselves.

[1] Lowell lectures.

His successor, Aristotle, was inclined to a more objectivistic view, since he wished to ascertain the fundamental generalities by direct observation as well as by pure reasoning. He was led to the invention of formal logic, no doubt with the exemplar of geometry in mind, and defined the fields of the sciences.

Thus Greek thought advanced far enough to appreciate the penetration of nature and mind with law. Perhaps its incompleteness was most conspicuous on the subjective side.

With the Renaissance, philosophers began to examine more closely the immediate deliverances of inner experience. The familiar dictum of Descartes, *Cogito ergo sum,* illustrates the new type of starting point. This introspective attitude created an immediate extraordinary change of appearances. Descartes proposed to account for the difference by adopting a dualistic view of the universe in which nature and mind were opposed. Leibnitz envisaged instead a world of self-subsistent thought monads. Both of these men appear to have been somewhat misled by their mathematical successes, so that they overestimated the power of pure reasoning. Contrary to the Aristotelian spirit, they attempted an *a priori* treatment of the universe which seems to-day largely formal arrangement.

One difficulty which philosophy was then laboring under deserves to be explicitly pointed out, namely, the uncritically accepted notion that objects were seen even as they were in essence. For this reason, Locke achieved a substantial advance by classifying certain properties of bodies, like size and shape, as primary, and other qualities, like color, as secondary since they exist only as sensation. Berkeley's doctrine that *esse* is *percipi* went still further in the same direction, while Hume adopted the extreme position that nought was real save impressions of sense and ideas.

The psychological ideas of Locke and the physical ideas of Newton, in particular the latter's corpuscular theory of light, fixed an apparently impassable gulf between the knower and the known. Nevertheless, space and time were still held to have an *a priori* character of necessity. It was in this way that Kant, near the beginning of the eighteenth century, was led to his objectivistic phenomenalism with the knower forever separated from the thing-in-itself, and perceiving it only under space and time as a form of the understanding.

Hegel abandoned the Kantian idea of an inaccessible reality behind knowledge. He centered on the dynamic aspect of consciousness in its continual passage from the actual to the abstract. More recently, Bergson has analyzed consciousness from a similar position. For him also the starting point and goal lie in directly

given knowledge, but he finds the essence to lie in a creative evolution of thought in duration, this duration being unmodified by treatment as an abstract moment of time. Thus Hegel and Bergson achieve a return to complete Berkeleian subjectivity.

It is apparent that, from Descartes to Bergson, all the philosophers mentioned have taken their point of departure in a new psychological insight.

Similarly, the development of biological thought has been the inspiration of the philosophy of Spencer and of a whole correlated movement.

Thus it appears that the main lines of approach to nature and mind are mathematical, physical, biological, psychological and social, and constitute a kind of hierarchy. In each, a few characteristic notions are fundamental, while all else is relegated to a minor place. The following classification indicates each of these main divisions, a corresponding typical system of philosophy and some of the leading ideas:

Mathematical, Absolute Realism;
Class, Relation, Inference, Abstraction.
Physical, Materialism;
Space-Time, Matter, Electricity, Uniformity.
Biological, Detailed Naturalism;
Organism, Stimulus, Function, Evolution.
Psychological, Positivism;
Sensation, Memory, Will, Idea.
Social, Ethical Idealism;
Personality, Freedom, Value, Ideal.

Of these, the earlier are objective, the later, subjective in outlook. The test of the objectivity of the mathematical and physical levels in this nature-mind spectrum lies in the fact that active thought at these levels goes on without any explicit reference to mind; the thoroughgoing subjectivity of the psychological and social levels is revealed by the opposite condition; the biological level is clearly of an intermediate type.

The position of a technically developed philosophical system may fall at an intermediate level; for example, pragmatism is biological-psychological in its structure. In all philosophies, supreme "reality" is attached to the primary level, while the secondary levels are held in some sense to be derivative. For instance, on the biological level, inference is merely a process of thought which "works"; and, on the psychological level, space appears as a complex of visual and tactual associations.

The naming of the nature-mind spectrum is a matter of interest. If we are objectivistic in tendency we call it the Absolute; if subjectivistic, Knowledge.

In my opinion, the fact that these levels are independent to the extent of being largely self-sufficient indicates that the best method for the philosophic grasp of the whole is to take the various levels as of coordinate importance and reality. At least this is the reasonable philosophic view of most value for the ordinary man, even if it be merely a kind of naïve realism.

The greatest direct philosophical influence of the physical theory called relativity lies at the physical level in the nature-mind spectrum, for it affects the meaning of the fundamental terms.

The classical concepts of absolute space and absolute time are replaced by a combined space-time. Time apart from space and space apart from time lose their intrinsic significance. The new element is the event, and the new underlying basis is the four-dimensional space-time continuum of events.

The matter and electricity in space-time are now thought of as affecting its very structure. Uniformity of physical law still holds, but this uniformity requires effects in the physical realm to be locally transmitted in the spatio-temporal sense, whereas, in the older view, the "state" of the physical universe at one "instant" affected the immediately subsequent states throughout all space.

Whitehead[1] has carried the new view of nature back to the mathematical (*i.e.*, logical) level, by showing how space and time arise from his standpoint. In consciousness there is the directly "discerned" and also the ultimately "discernible." Classes of events are what are discerned, and these are interrelated through compresence or lack of compresence in consciousness. Thus an event is a "slab of nature." The technical relation between events is that of spatio-temporal inclusion. The method of extensive abstraction then yields the notion of the idealized event or point-instant as a collection of the slab-like events mutually in the relation of inclusion. The method is such that the space and time determined are clearly relative to the individual. A point is merely a collection of events with the same three space numbers; an instant is a collection of events with the same time number.

As is indicated by Whitehead, the approach to space-time given in these general terms becomes definitely mathematical under technical elaboration. In this form it is an abstraction of space-time, capable of giving the same kind of service for the new theories as various other logical systems perform for ordinary space; it is similar in structure to Huntington's system for ordinary space, in which the sphere is the undefined element, while the undefined relation is inclusion. It is on this account that the analysis belongs entirely at the mathematical level.

[1] "The Concept of Nature," Cambridge, England, 1920.

With space-time so analyzed, the object can be defined as a collection of events united by a certain kind of common modality. The aim of the physical sciences is then to specify the uniformities underlying the behavior of such objects in space-time, in terms which are essentially independent of the arbitrary method of space-time measurement selected.

It is plain that Whitehead builds in this way a mathematical approach to the new theories of philosophical type just because the general logical aspects, rather than the technical mathematical ones, are stressed.

Similarly, Bergson[2] has pointed out an interesting parallelism between his own speculations and the subsequent theories of relativity. He had taken the notion of duration, unmodified by intellectual analysis, to lie at the basis of experience. Now in the new theories the notion of the measurable interval of local time serves as the basis for the subsequent technical construction of measurable space and time. Hence relativity affords a certain independent justification of the validity of Bergson's prior conclusions. Moreover he has called attention anew to the reality of the notion of duration from the psychological point of view, in that two beings can identify themselves in thought, and so in duration. Yet there are two kinds of simultaneity, as in relativity. "The first," says Bergson, "is interior to events, it makes part of their materiality, it originates in them. The other is simply attached to them by an observer exterior to the system. The first expresses something about the system itself; it is absolute. The second is changing, relative, fictitious, it originates in distance."

If we consider the flow of time for all beings, it is clearly not possible to conceive of this multiple time as a simple flow without distorting its inner nature. To a certain extent, therefore, Bergson's refusal to treat time abstractly acquires justification.

These reactions of Whitehead and Bergson are sufficient to indicate that relativity is proving very suggestive at the mathematical and psychological levels.

Haldane[3] has attempted to apply the "principle of relativity," even at the social level, in dealing with society and the state. But here he is referring to a long established principle largely to be found in Plato, as the following passage of Haldane's makes manifest:

The real lesson which the principle of the relativity of knowledge teaches us is always to remember that there are different orders in which both our knowledge and the reality it seeks have differing forms. These orders we must

[2] "Durée et simultanéité," Paris, 1922.

[3] "The Reign of Relativity," New Haven, 1921.

be careful to distinguish and not to confuse. We must keep ourselves aware that truth in terms of one order may not necessarily be a sufficient guide in the search for truth in another. We have, in other words, to be critical of our categories.

This is substantially only the doctrines of the differing levels of thought, stated above.

There is, however, a sense in which relativity can be made to throw further light upon the mathematical–logical factor in mind and nature, namely, as a typical instance of the abstraction. This is only the case because the familiar classical abstractions of space and time have been held sacrosanct and qualitatively different from all other abstractions. But the theory of relativity has made it clear that it is not yet possible to decide what will be the final abstract form which physical theories will take, even in dealing with space and time.

In consequence, certain elementary truths about abstract structures at any level of thought have not been properly appreciated in the past. It is to these truths, as instanced in relativity and applicable in a measure to philosophy, that I propose to turn in conclusion.

The word "abstraction" is to be interpreted here in a very wide sense. When a primitive man looked at the sun and the moon, it must have been obvious in his mind that there was a similarity about the two objects. Here the perception of likeness amid difference is the nascent intuition, the forerunner of the symbolic abstraction. The same fact in the language of the early Greeks would have been expressed by saying that the sun and moon were spherical in shape. But the entire meaning of such a statement was latent in the perception of the primitive man. Moreover, even the Greeks used various intuitions in their geometric reasoning which were not explicitly stated. Within recent years, however, symbolic logic has become available as a calculus (*i.e.*, a very brief complete language in which the words are symbols) with which to deal with abstractions. Certain postulates (*i.e.*, intuitive inferences) are stated in explicit form, and then by a chain of inferences all the latent meaning of the systematized abstraction is developed. Thus the abstraction appears in three stages: the nascent or purely intuitive stage, the stage of systematic elaboration and application, and the completely symbolic stage.

The various stages of an abstraction can be given a very simple exemplification in the abstraction of (local) time. The first stage is that in which it is perceived that the order of events will be *A, B, C,* etc. In the second stage the notions of "before" and "after" will have been embodied in the symbolic word so that *A* will be declared to happen before *B,* etc.; at the same stage it will

be held intuitively obvious that if A happens before B, and B happens before C, then A happens before C—a postulate; events will be numbered, so that arithmetized time is available in dealing with events. In the final symbolic stage the notion of an instant of time will be arrived at by abstraction of the time continuum. It will be proved that with the class of "instants" as undefined elements, and with "before" as undefined relation, and obvious postulates, the time continuum can be completely characterized. This is the third and last step. The final abstraction seems to stand out and exist apart from any concrete embodiment of it in a very remarkable way.

Thus, properly interpreted, the abstraction is of transcendent importance. Only by means of the complementary process of abstraction and experiment is it possible to extend knowledge.

The first general principle referred to is essentially that given by Haldane, and may be stated as follows:

I. Every abstraction is to be applied in its appropriate domain of validity.

For example, the geometry of Euclid idealizes static spatial relations although none are exactly static. The special relativity holds only for empty space-time, and, while space-time is nearly empty of matter in certain parts, it is not exactly so. Likewise, the general relativity assumes that there is no limit to the indefinitely fine structure of matter.

However, all these particular abstractions apply at the physical level. At the other levels the abstractions used are far less exactly applicable, in particular because the meaning of the various terms is not susceptible of equally precise technical definition.

This seems to be more or less in the nature of the case, since only physical entities are presumed to be elementary, while those of biological, psychological or social type are statistical (although not less important on that account).

II. As more complete abstractions are made, they may be expected to include their predecessors.

Thus, in a sense specified previously, the special theory of relativity includes the classical theory, as the case of very small relative material velocities; and the general theory of relativity includes the special, as the case when matter is very sparsely distributed.

In general, the advances in the physical and psychological sciences, as well as in philosophy, suggest that new abstractions contain their predecessors in some sense or other.

III. The undefined elements, relations and postulates of a particular abstraction are to a large extent arbitrary.

For example, the solid may be made the element in ordinary geometry, as well as the point. In the latter case the undefined

relation may be "betweenness" or "separation." Similarly, in relativity we may take the four-dimensional extended event or the point-instant as the element; and in the latter case the undefined relation may be "local time" or "local distance." The range of choice is always very large, and there are many interesting possibilities besides those referred to.

Hence, even though the undefined elements, relations and postulates are selected so as to have a large degree of self-evidence, the choice made is by no means determined by this requirement. If two available sets of undefined elements, relations and postulates are considered, either can be completely interpreted in terms of the other. Hence actual difference in conclusions does not follow from the difference of terminology. The essential item is that all elements, relations and postulates from the one system can be systematically interpreted in the other, and *vice versa.*

On this account, the fact that there are many philosophical systems does not necessarily imply any essential differences between them, except in so far as the meaning of the terms used can not be consistently interpreted back and forth. For example, suppose that one philosophical system regards as real only what lies at the physical level, and a second such system holds to the superior reality of the psychological level. Notwithstanding this difference, it may be possible for either to interpret technically the kind of reality used by the other. The mere difference in usage of words is not significant. Of course, if the abstractions have reference to ascertainable fact and differ in a substantial way, experiment will reveal which of the two is correct. However, since systems of philosophy do not differ about the facts at the various levels as much as about their interpretation, it seems patent that such systems may be abstractions with different undefined elements, relations and postulates, but otherwise in satisfactory harmony.

IV. The usefulness of an abstraction is relative to its inherent simplicity of structure and its agreement with the facts.

For example, the usefulness of the theory of relativity depends on the circumstance that it possesses the same inherent simplicity as the classical theory, while it explains more facts than that theory did.

Similarly, a philosophical system possesses merit only in proportion to its simplicity and capacity of accounting for the facts of mind and nature.

Thus the true rôle of the systematized abstraction becomes apparent, and freedom is won to use a formula or theory and yet not be enslaved by it. Undoubtedly relativity has acted as a salutary influence in this direction upon the entire field of human thought.

THE SOUTH AMERICAN INDIAN

By Professor WILLIAM H. HAAS

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MORE or less periodically, newspapers give considerable space to the discovery, somewhere in the western world, of fossil bones, purporting to be human or prehuman, of great geologic age. Patagonia is a good place to have such bones discovered, for the region is sufficiently unknown to most people to be more or less clothed with strange possibilities. Not long ago such a report again emanated from there, and a little earlier from this general part of the world came also the story of the living plesiosaur, the held-over Cretaceous reptile. Such stories are common and, having a grain of scientific truth in their write-up, make good newspaper copy. They belong, however, to the same order as the discovery of a living mastodon in Alaska, or to the seeing of an enormous sea serpent off the Atlantic coast.

The latest South American find is a skull purported to be from the *early* Tertiary. This find, if authenticated as to age, would be a most startling discovery and well worth a place on the front page of any newspaper. Fossil human records of late Tertiary (late Pliocene) age are established and fossil human bones in South America also are known, but to find such bones of Tertiary age in South America would seem an impossible combination.

From geologic history we are led to believe that the same animal form originates but once, and that its birthplace, so to speak, is in a rather restricted area. From this center the animal may spread until prevented by barriers, or it may become adapted to new environments by physical changes. We are not sure of the exact birthplace of man; most probably it was in southeastern Asia; but we are quite sure that it is not in either of the Americas. Therefore, to find a Tertiary man in South America would mean, to say the least, a most astonishing migration and early dissemination. That there may have been early migrations to the American continent and that the migrants may have become extinct is a possibility. Professor Osborn recently reported on the finding of a remarkable tooth in Nebraska taken from the middle Pliocene which shows wear both by use and by erosion. The tooth is not like that of a gorilla, gibbon or orang, but most like that of a chimpanzee, and is thought to be intermediate between ape and earliest man. This anthropoid may have been part of that large migrant group of Asiatic fauna

recently unearthed in our west. The tooth was found with the remains of rhinoceros, camel, Asiatic antelope and an early form of horse. This is the only specimen of the primates discovered on the American continent and has been named Hesperopithecus haroldcookii.

It must not be concluded from the discussion above that man's early development was along such a narrow line that a chance death of an individual or even of a whole species might have eliminated all that the human tendency had in latent store. Just as many species and several genera of horses developed and have been found fossilized on our western plains, so we know, according to the classifications made, at least four genera and six species of man in fossil record from the Old World. In the case of the living horse group, we have only one genus and four separate species remaining, *viz.*, the horse, the ass, the zebra and the quagga. The latter is probably extinct now, also. In the case of living man, we have only one specie remaining.

The difficulty of determining the age of fossil man accounts in part for the credence given to stories concerning him. To say that a fossil belongs to this or that formation or period is in most cases not difficult because the determination is only relative. However, in determining the age of human fossils, a determination which demands great precision, the problem takes on an entirely different aspect. Man is so very recent geologically and requires such precision in his age determination that the ordinary methods used may lead to very divergent conclusions.

The age of rocks and the fossils in them is determined by the very simple principle that younger rocks are laid down on older. Accepting this so-called "law of superposition," we can trace in the fossils contained therein certain biologic lines of descent through the rising stratigraphic column. After a line of descent once has been worked out, such a record with some of its associated fauna can be used as time markers for other regions. With man, however, other fossils are of little value because little change has taken place in their forms since his advent. Likewise, the upper part of the stratigraphic column has been divided and subdivided into such great detail, relatively, that slight differences in interpretation may lead to conclusions wholly irreconcilable.

In the case of man there are other difficulties as well. Man is a digging animal, and there is always the question of a possible introduction subsequent to the formation of the matrix which encloses the bones. Also all the older fossilized human bones have been found in alluvial deposits where they have been laid bare by erosion. Through erosion or slumping the bones may have been

carried to a much lower level than the one originally buried. The later human fossil record is from caves where the determination is made largely on the basis of the bones of other animals associated with the remains. Even if these and other questions are satisfactorily settled there still remains the interpretation of the fragments in hand. As a rule, so little of the original is left that a true reconstruction in most cases is highly improbable. One of the finds in Argentine, which at first created so much interest throughout the world, owed its scientific publicity to the fact that Ameghino, its sponsor, in his drawings, had given the skull an orientation which, when other scientists went there to study the find, could not be accepted. Besides, in most cases the determination is made from a single specimen and in such a case we can never be sure that the specimen in hand is a true representation of the degree of development of that period. The characteristics noted may be due merely to an abnormality, or to a reversion of this particular individual.

In the new world many finds of various geologic ages have been reported, but none have been accepted generally as establishing either Pliocene or Pleistocene man. In South America there seems to be a predilection for the Tertiary, in this country for the glacial period, yet, without great reservation, no fossil record, except that of the modern Indian, can be accepted. Europe, we know, had its glacial man, but, so far as we know, the glacial period did not disturb any human beings in the new world. There was no race here preceding the so-called American Indian, and he, it is generally accepted, must be thought of in terms of cultural traits rather than in terms of organic evolution.

Cultural Evolution

The study of the origin and evolution of the American Indian is at present much neglected, especially by the student of geography, in spite of the fact that here is one of his richest fields of research. This neglect is all the more serious because the old cultural traits of the red man rapidly are disappearing, and the field for research is becoming increasingly more difficult. Cultural as well as physical evolution is clearly the result of environment, and nowhere else can this influence upon cultural evolution be traced so clearly and so sharply as upon our American Indians. They are the real creatures of their surroundings, and at the advent of the white man still lived in the same general environment under which they had developed. These conditions, however, have been gradually changing due to the influence of the white man.

The white man has brought a new cultural environment. In

this country the Indian has been shifted very largely from the region of his ancestors and put under new physical conditions. In South America, where the white man and the Indian have intermarried so freely, the two orders blend; yet the influence is dominantly that of the white man, since the Indian has adopted many of the ways and products of the more powerful race, although he is still in the same general physical environment. His fate no longer is in his own hands, and he lives and acts under the direction and influence of another culture. Only in parts of the Amazon Basin can any considerable group be said to be untouched by white influence.

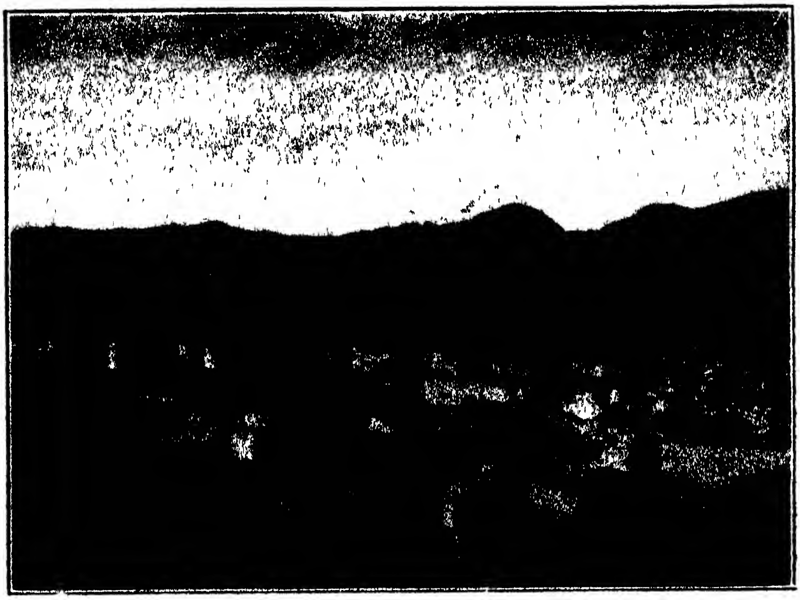
In the study of our own progress it is interesting to speculate as to what effect slight differences in our cultural environment would have had. What would be our status had there been no such minerals as iron and coal. What we owe to the horse, or even the lowly silkworm, are not easy questions to answer. If there had been no such animal as the hog or plant like corn, what would Chicago be like? If Mars is inhabited by a highly cultured race, did the Martians pass through the stone, the bronze and other ages? Do they have something which they use as exchange, over which we worry so much when we have it and still more when we do not have it? Is their life organized on the individualistic basis like our own, or is it communistic like our Indian civilization? Do they emphasize the things we do, or have they a different viewpoint? Such questions can be multiplied without number, perhaps to no purpose; yet that situation is exactly what the European saw, but didn't appreciate, when he first set foot on the new world. We haven't appreciated the fact fully yet that here in the new world had evolved a new culture which paralleled the European in time, but was as different in kind as was the environment which produced it.

The white man not only had an opportunity to study a living civilization almost as distinct as though it had been located on another planet, but also saw what were, even then, antiquities of other civilizations that had risen and disappeared. It never occurred to him that here was a civilization that had risen without the use of minerals and without beasts of burden. He did not realize that here was a culture that had surpassed his own in social organization. To him the Indian was merely a savage, and the white man was naïvely ignorant of the fact that most of the savagery was practiced first on his own side. Even to this day, in the minds of many people the words "Indians" and "savages" are synonymous. Had the history we read been written by the red man the story would be a different one. To the Indian, on the

other hand, the white man seemed of a low order, for the paleface made treaties seemingly only to break them. Why should he promise so much and live up to so little? The Indian never could understand the white man's insatiable greed for the yellow metal for which he was ready to lie or steal or murder. To the plateau Indian of South America gold had no value except when made into objects of art and worship. The white man not only took these objects, but set out at once to destroy their value by melting them down into shapeless masses. One civilization had made values that the other knew nothing about. The use of gunpowder and lead and treachery saved the day for the one and lost it for the other.

The general notion has been long too common that the Indians, wherever found, were savages without any development, and that regions like Peru, Central America, Mexico and our southwest must have been peopled by a race, or at least a strain, of greater actual potential possibilities in order to have advanced along certain lines beyond those of other sections. Careful study has shown this not to be so. Each region produced its distinctive culture according to its environment with a minimum of outside influences. The Indian was limited in his migrations to the distances his own feet could carry him. All his supplies and the fruits of his forages were transported on his own back, for he knew not the use of the wheel, nor had he domesticated any animals sufficiently strong to carry him. Consequently, his migrations were limited to the regions sufficiently similar to furnish the kind of food to which he was accustomed. Thus, each type of food-area produced a culture which was a distinct product of that area. Because the southwest Indians built homes of a thousand rooms does not make them more civilized than the plains Indian with his skin tepee, or the eastern forest Indian with his block huts. The fact is the one was skilled in one line while the other had advanced in another. The difference between the agricultural Indian of the plateau and the roving hunter of the plains was largely a matter of emphasis. In point of view it was a difference between one who travels and one who stays at home. In the case of war there isn't much doubt as to which of the two would win. We can not use our civilization as a measuring stick in gauging another which climbed a totally different ladder; nor can we select one Indian trait and measure all other groups by it. The Indian wherever found was a product of his particular environment and did not show by cultural traits different innate ability.

Accepting this point of view, many attempts have been made to group Indian cultures around some fundamental principle. The problem, however, is not simple, for many factors enter into what



THE RUINS OF PACHACAMAC, NEAR LIMA, PERU
These enormous structures were built of adobe, the common material available. Here are found the huge underground cisterns, some of which are still in excellent condition.

comes under the general name of culture. From an evolutionary point of view, the most satisfactory working hypothesis seems to be that based on the type of food used, for its search, as an ever-present urge and not to be pretermitted, directs most of the primitive activities. The nature of food available is also most closely allied with topographic and climatic conditions, especially with the natural plant and animal life. Conversely, the life of a region, including primitive man, gives, in the main, the best all-round view of the physical environment. Since physical conditions vary from place to place, so food possibilities also vary and, similarly, culture also will vary.

The number of culture areas under primitive conditions will depend, therefore, on the number of areas which produce, in general, the same type of food. Such areas thus become natural or geographic regions, limiting, in the main, migrations. Wissler[1] divides South America into four culture areas. These areas again may be broken up because of minor differences within the group.

[1] "The American Indian," J. Clark Wissler, New York, McMurtrie. This most excellent book takes up both continents and contains a wealth of basic information.

THE BURIAL GROUND AT PACHACAMAC

Peru, in order to keep minor antiquities at home, has prohibited their exportation. As a result no excavations are made by reputable organizations, but individuals dig and destroy to their heart's content in search after gold and silver ornaments to be sold surreptitiously, perhaps to be melted down. Embalmed mummies, wrapped in valuable old cloths, and other relics strew the ground.

At the present time, of course, in many sections, conditions are entirely changed; yet where the Indian blood still remains these conditions remain more or less the same. The divisions are as follows:

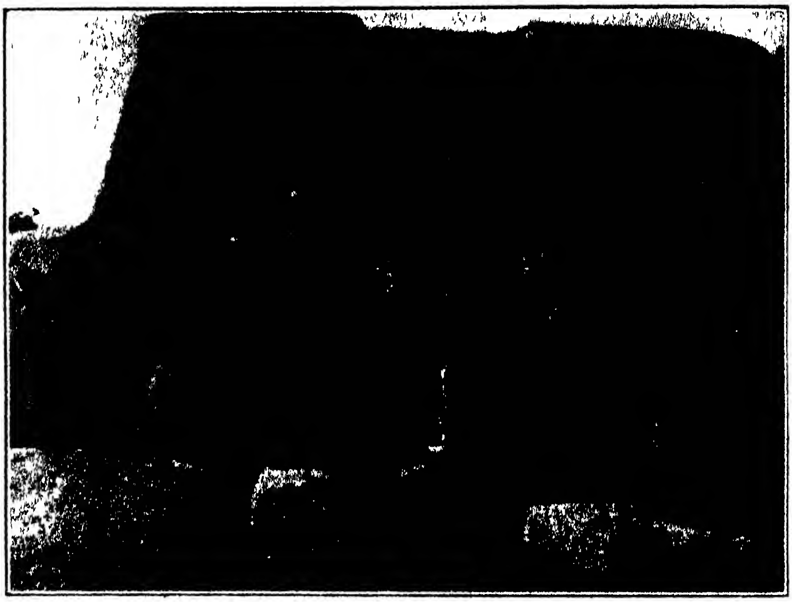
The Chibcha area, which included also part of Central America, centered around Bogotá. These people were agriculturists, growing potatoes, beans, maize and other minor food products. They grew cotton also and had developed a high technique in spinning, weaving and dyeing. There were great markets where a kind of currency was used. Taxes were paid in gold and cloth. To facilitate marketing, roads were built and suspension bridges crossed many rivers. They had no beasts of burdens nor knew the use of metal tools. Their advance seemingly had been reached until some new factor should find entrance into their lives.

The next group developed around the manioc of the Amazon Basin and was, therefore, largely agricultural. It is to be remembered that South America is largely tropical and that fully one half of it lies within the Amazon basin. Most people think of tropical wilds as a place where food is extraordinarily abundant,

THE RUINS OF THE GREAT INCA FORTRESS, SACSAHUAMAN, AT CUZCO
The enormous size of some of the stone blocks may be estimated by the size of the man in the middle foreground. One block is said to measure 27 ft. by 14 ft. by 12 ft. This stronghold may be older than Cuzco itself.

but nothing is farther from the truth. The idea is common because of the luxuriance of tropical growth and the prolificness of a few plants. Food in its natural state is not abundant, either animal or plant. Because of the lack of native foods, agriculture had to be practiced, and manioc, or cassava, was the chief crop, taking the place of the maize of other sections. Besides this, the Indian grew sugar-cane, peppers, pumpkins, tobacco and other minor products. Here, as elsewhere, the environment determined the traits, and the conditions were too severe to develop anything unusual. Without going into detail, it may be well to state that the supposedly enervating conditions of the tropics did not have a particularly debilitating effect upon the natives, for they largely had become immune to the native diseases. Whatever, at present, the effect on the white man, one needs only to recall the names of the two leading tribes, the Caribs and the Arawaks, to bring to mind the virility of these groups. These tribes were equal to the Araucanians of southern Chile, and surely superior to the Quechua and Aymará of the Inca Empire.

The third culture group is that of the plains of the south. It has received its name from the dominant animal of the pampa,

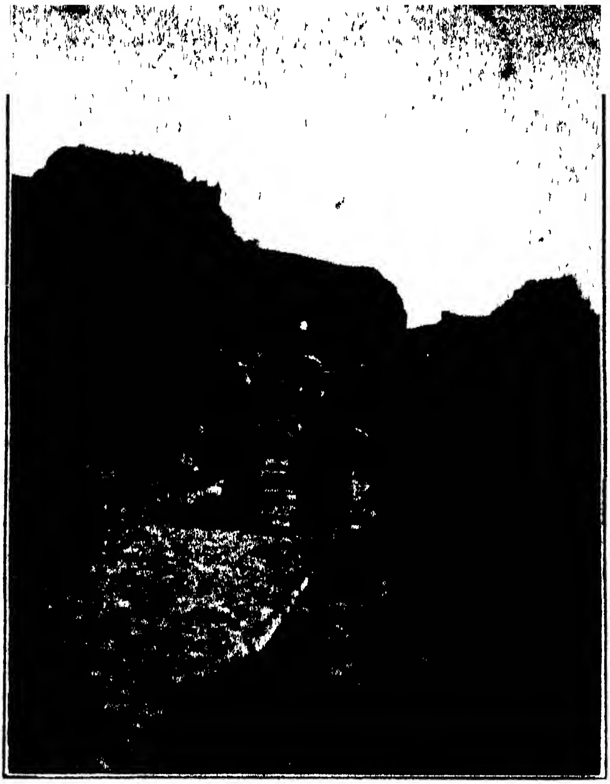


A PART OF THE WALL OF SACSAHUAMAN

The building of this fortress is considered the greatest achievement of man in America The great size of the stones and the precision with which one was fitted upon the other, so that not even a knife blade can be thrust in between, places this well into the front rank of American antiquities. The carrying case hanging in the middle foreground is for a number 3 kodak.

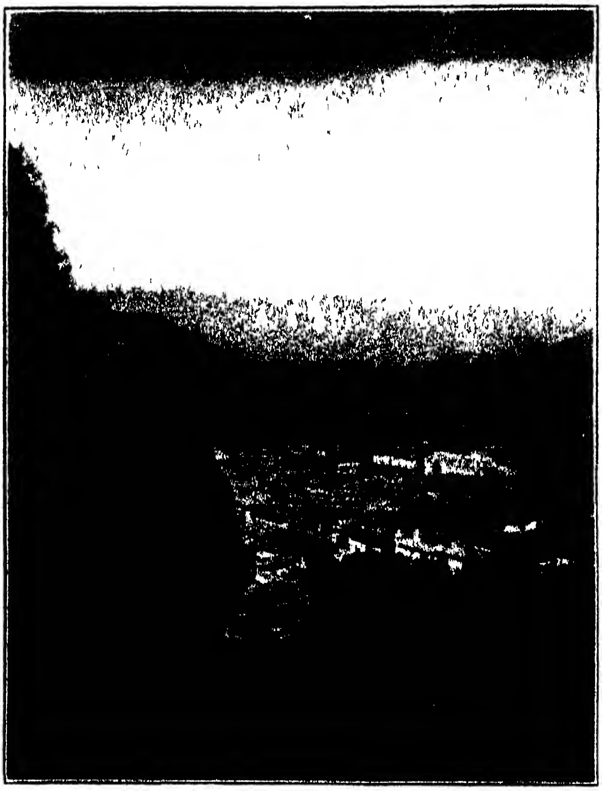
the guanaco This fleet little animal is one of the camels that had migrated from the northern into the southern continent, and became adapted to the plains, whereas the llama, alpaca and the vicuña are the product of the plateau The guanaco culture is much like that of the buffalo culture of our plains Indian. They both depended on the chase, where the life of one centered around the buffalo, that of the other could not have existed without the guanaco. These hunters did little with crops or with weaving but developed great skill in leather work After the Spanish introduction of horses and cattle, the life centered around the horse, and there developed what has been referred to in our own country as "the horse culture" As might be expected, the pampa developed some features not found in North America, such as the bola, the lasso and the toe stirrup There were many minor differences also, such as the tepee's giving way to the lean-to, or to the tent with the ridge pole, but the similarity is much more striking than the dissimilarities.

The fourth group is that of the Inca Empire. The northern border of this area is in Ecuador and the southern in Chile. The



An Old Inca Road leading out of Cuzco
These roads were not built for vehicles and in certain places resemble a stairway more than a road. The group leaving Cuzco is, on the whole, typical

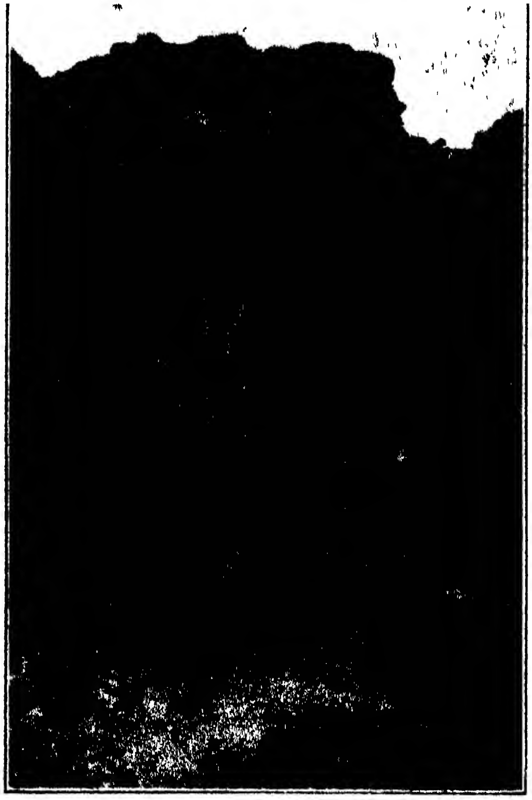
culture is a highland one, yet evidences of it are found in the lowlands. The dominant languages were the Quechua and the Aymará, and these tribes make up the dominant stock to-day. They had a highly organized government in which authority was vested in a council which appointed from a hereditary group a war chief or Inca. Hence the name. Agriculture was highly developed, both in variety of products grown and in amount of production. The main crops which they irrigated and manured were maize, potatoes, manioc and peppers. They had domesticated animals such as llamas, dogs, guinea pigs, monkeys and birds. Some of the animals were merely pets. From the cotton grown and from the llama and vicuña wool, they spun beautiful cloth showing exquisite taste in their elaborate weaving designs. All sorts of clay work reached a high degree of perfection. Gold, silver and copper ores were mined and smelted and even true bronze was



CUZCO, THE ANCIENT CAPITAL OF THE INCAS,.
as seen from the road to Sacsahuaman. The town is still the Mecca of the Indians of Southern Peru, some of whom are said to salute it still as in the days of old Parts of it bear out the appellation of "one of the dirtiest cities in the world"; but it is also one of the most interesting cities where both ancient and modern pique the curiosity of the traveller.

made. They built roads and suspension bridges. There was no writing, but they had counting devices. There was an organized priesthood with confession of sins and religious orders of virgins. They had also a deluge myth and offered animals as sacrifice to the sun god This was the civilization torn by internal dissension to which the gold-crazed Spanish Conquistadores came.

All these culture groups, each with a fairly definite unity of culture but shading out at the borders, were the products of conditions under which they lived The strange part of it is that the best and most virile stocks, like the Caribs, Arawaks and the Araucanians, had not risen the highest according to the white man's standards. They left no enduring monuments to their industry and skill such as have been left by the more mediocre plateau



A DOORWAY OF OLLANTAYTAMBO IN THE URUBAMBA VALLEY BELOW CUZCO

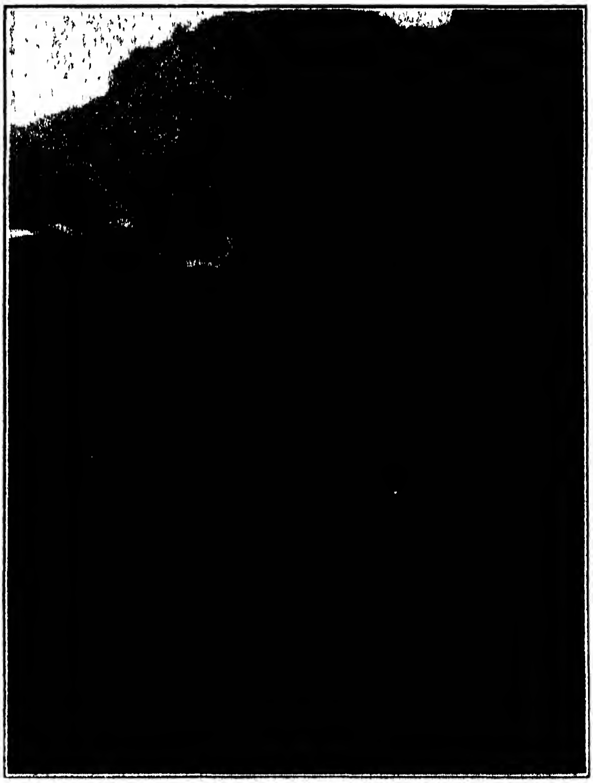
This fortress is believed to have guarded the plateau peoples from the savage hordes of the montaña along one of the easiest passes With great care each stone was lifted upon these below Machu, Picchu and Rosaspata are still farther down the valley.

groups. This easily is explained by the fact that such monuments are the result of group activities and that group life is the result of a congestion of populations. This congestion, in its turn, under primitive conditions, may produce a certain degree of degeneration. This thorough adaptation of a large group to the region which it occupied shows conclusively that the Indian can not be a recent immigrant spreading rapidly over the two continents. His very provinciality and evident lack of transferred culture emphasize his early distribution and adaptation. The use of certain customs or leftovers by widely separate groups, on the other hand, clearly points to a common origin.

THE GREAT FORTRESS OF PISAC

was built at the upper end of the Urubamba pass This structure never was finished. The rows of stones at the base of the walls were never put in place. Here are some of the most remarkable series of terraces. Every foot of ground that could be terraced and cultivated was made to produce its share of food. Some of the terraced slopes may be seen in the background.

Accepting that the Indian advanced in one direction or another according to the conditions under which he lived, there are still many questions to be answered · What was the original culture from which all these variants sprang? It has been demonstrated quite satisfactorily, to many students at least, that the American Indian is closely associated with certain hill tribes of eastern Asia Granting that the early immigrants came from there, we must ask, were they all from one stem, and granting this, were they all from one migration? Here many difficult problems clamor for a solution and the most vital of all in the study of Indian culture is, What did he bring with him and what did he develop here? There are various possibilities in the degree of culture attained by the time he became a migrant to a new world He may have left early, at the very threshold of his cultural career, and having become separated from his fellow-man by geological changes, he may have become culturally fossilized, somewhat after the manner of the primitive mammals of Australia. This would seem strange, since the country is so large and conditions are so variable . There doesn't seem any



A Stairway at Pisac

It is hard to believe that these stones were dressed and fitted into place with no other than stone tools.

lack of stimulation to peoples at the present time. On the other hand, he may be a relatively recent arrival from a degenerative stock bringing with him fundamentals that led him into blind alleys. Unfortunately, we know so little of the hill stock of eastern Asia that the answer to the question seems insolubly to be bound up with the anthropological investigations of that part of the world. With a greater knowledge of the Asiatic culture we may hope to answer some of the questions seemingly unsolvable to-day.

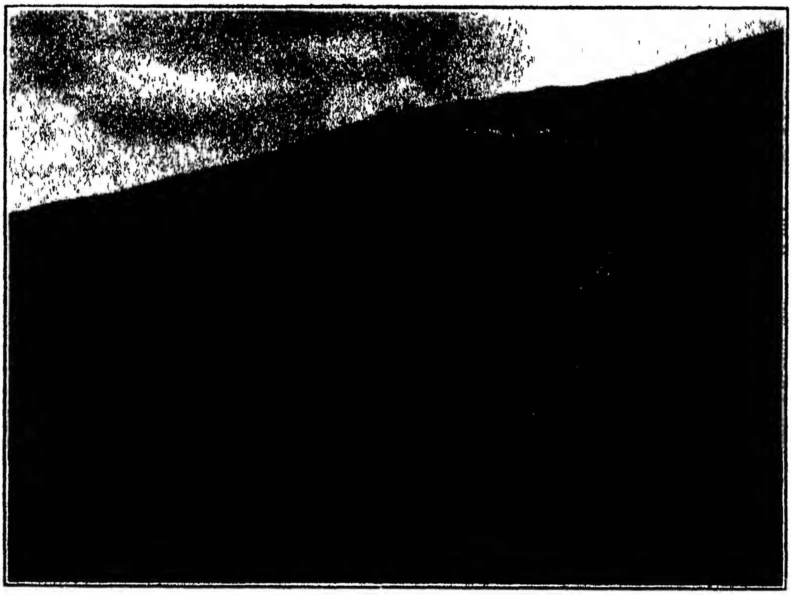
A host of other problems also arises, and the whole question relative to the differentiation of Indian cultures becomes most complex. Even if the ancestors of the Indians crossed over from Asia early, in one group from one stem, how and when did this migration occur? Did the dissemination throughout the two continents come suddenly in another Tower of Babel way, or were there many departures from the original center or centers separated by long intervals of time? After one culture had been established did an-

THRESHING GRAIN

gathered from the terraced slopes near Pisac. The Biblical injunction of the laborer being worthy of his hire is evidently not needed here, when in some of these valleys, it would not be hard to make-believe that time had dropped back into the days of Abraham.

other come and displace it, similar to the Hun invasion, and did this culture, in time, pass through the same development that its predecessors did? If similar traits are found in widely divergent groups does that mean a sameness of origin, a sameness of conditions, or a sameness of something else? Or did these similar traits come into existence separately and absolutely independently? Our knowledge of the American Indian is so meager as to leave most of these questions unanswered

We do know, however, that evolution is an extremely slow process. Social and cultural as well as physical evolution is, in the main, largely through mutations. Cultural traits, when once established, are most resistant to change and, as has been shown in so many ways in the history of the white settlements in this country, the whole social fabric is transplanted *en masse,* and such social customs survive in the new environment long after the conditions which brought them into being have passed away. New things come only with pressure and this never becomes very strong until populations become fairly dense and the few resources laid hold of no longer supply the needs. Progress comes with the laying hold



IN THE CUZCO VALLEY

alluvial fans offer excellent crop conditions. The soil is rich and the substratum is kept moist by the run-off from each little shower. The widespread use of the steep hill slopes, as well as the flatter hill tops, is a never-ending surprise.

of the untouched resources of the region and the more effective use of the old.

Probably the greatest factor in the relative stagnation of the American Indian was the sparsity of population. The continents were large and the time, probably, had not been long enough to give a dense population. The culture groups also were so much larger than the tribal units that intertribal killings kept down the number. Perhaps the greatest factor of all was the relative infertility of the Indian woman and the extremely high death rate among young children, if one can judge by present-day conditions. The few advanced centers of a more advanced culture were peopled, most likely, by weaker and less competent tribes driven from the better sections. These tribes, freed from intertribal killings through natural barriers and situated in regions where nature makes a lack of sanitary conditions least dangerous, may have multiplied to such an extent that necessity became the mother of invention and the tribes became somewhat expert along lines in which past experience became cumulative.

Whatever the absolute facts, evidence from several fields points to certain definite conclusions. The so-called American Indian is

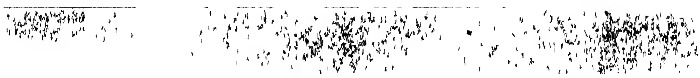
A PART OF THE HIGH PLATEAU OF PERU

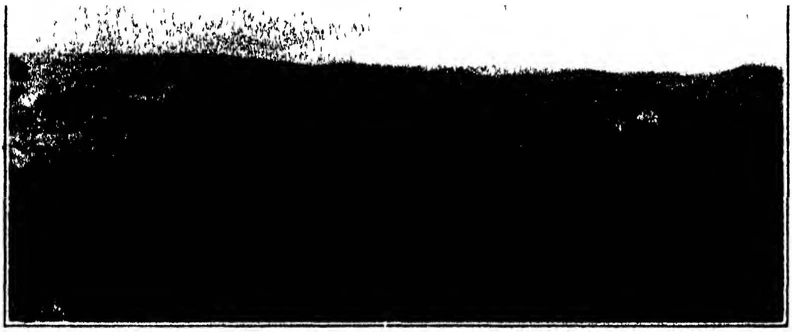
along the route from Oroyo to Cerro de Pasco The stones have been gathered into rows and piles and the land formerly worked between them So much gathering of stones has been done that many natives of the region insist in all seriousness that the Indian still piles stones just for the sake of piling.

of mongoloid stock reaching the New World with the cultural background of the stone-polishing stage. According to Hrdlička[2] "the immigration, in all probability, was a dribbling and prolonged overflow, likely due to pressure from behind, or want, and a search for better hunting and fishing grounds in the direction where no resistance of man yet existed " There may have been, and most likely were, small accretions later on both sides of the continent; but, if so, no definite new elements of culture were added.

If this be accepted, then the culture of the American Indian is almost an entire cultural product of the New World. Just how old this American culture is can not be stated, even in relation to the white race, for the stone-polishing stage for Asiatics was not necessarily the same as for Europeans. At any rate, the progress made by the American Indian in the various arts was extraordinarily slow in comparison to those in his mother continent. That the culture of the American Indian is an American culture is not hard to believe, but that the Indian lived here quietly and com-

[2] Hrdlička, A., "The peopling of America," *The Journal of Heredity*, Vol. VI, pp. 79–91. (1915).





STONE FENCES AND STONE HOUSES WITH THATCHING brought up from the montaña is a sight which emphasizes the barrenness of the plateau and the severity of the living conditions This is an Indian village along the route to Cerro de Pasco.

placently for 25,000 years[3] or more while civilization rose and fell in each of the Old World continents does not seem credible. Such, however, seem to be the facts. The slight development, relatively, of the American Indian is one of the most interesting but most difficult problems to solve pertaining to the New World

THE INDIAN OF TO-DAY

During the period of exploration and colonization, the native was looked upon by the white invader either as a nuisance or as an aid. A good Indian was either a dead Indian or a slave. In sections where land was the thing wanted for homes, the red man had to be displaced, of course, for the land could not be occupied by the white man as long as it was needed for a hunting ground The two interests were unalterably opposed to each other, and the result was many wars and much bloodshed The Indian, however, inevitably had to yield before the oncoming hordes and he did it little by little, rarely in friendly spirit and with little mixing of blood. The few mixed bloods in Anglo-Saxon America came largely through the life-habits of the French voyageurs in the great in-

[3] See Osborn, "Men of the Old Stone Age," p. 23.

THE "VILLAGE GREEN" OF THE PRESENT-DAY INDIAN VILLAGE OF PISAC
The weave of the "poncho" and the shape of the headdress never fail to tell where the Indian comes from Styles never change and the badge, therefore, always tells.

terior, although at the present time in the southwest, due to the finding of oil on reservations, there is perhaps more mixing of blood than at any previous time

In Latin-America, in the main, the conditions were different. There the Indian, for the most part, was more valuable as a slave than dead, and there was no desire or need to dispossess him. The males were wanted for forced labor in the mines or in the sugar fields, the females for servants and concubines. There were no restrictions, and miscegenation could and did go on freely. In the West Indies, only after the Indian had been killed off by slavery was the negro imported. In Brazil the conditions were even worse because of the slave drives from the rich recruiting fields near by. The coast of Brazil, for a time the sugar source of the world, gained its rank at first under Indian and later under negro slave labor The "bandeirantes" of southern Brazil are famous, perhaps infamous, for their Indian enslavement expeditions. In Argentina, due to the lack of development, aside from the cattle industry, the Indian was crowded out rather than absorbed, as he could not be used. Modern progressive Argentina may be said to begin about 1870, and in 1879 there was an Indian drive to wipe

INDIAN WOMEN SELLING FRUIT
and other eatables to passengers and train crew at a station stop of the famous Lima Oroya Railway Trains usually stop long enough to do considerable bargaining for products on sale. Eating and travelling are hardly to be dissociated in South America.

out the last Indians The country, therefore, is fairly free from Indian blood except in the south and in the northwest. In Chile, likewise, the Indians were warred upon as early as the first half of the sixteenth century by the Spaniards in their thirst for treasures; and the brave Araucanians, fighting for their freedom, little by little were forced south into the more inhospitable parts where they still are and slowly are becoming absorbed. The number of mixed bloods, although greater than in Argentina, is nevertheless much smaller than in the countries to the north.

In the plateau regions the situation was quite different Here on the bleak, timberless, grass-clad punas had developed a culture not aggressive, but quiet and docile, trained to follow a leader They were an agricultural people holding their lands in common No one owned anything and there was no need for currency The lands allotted to the widows, orphans, sick and aged and to the absent soldiers were cultivated first. A story is told of a superintendent who was hanged because he caused the land of a relative of his to be tilled before that of a widow. There were no beggars because he who would not work was punished. Tribute and taxes

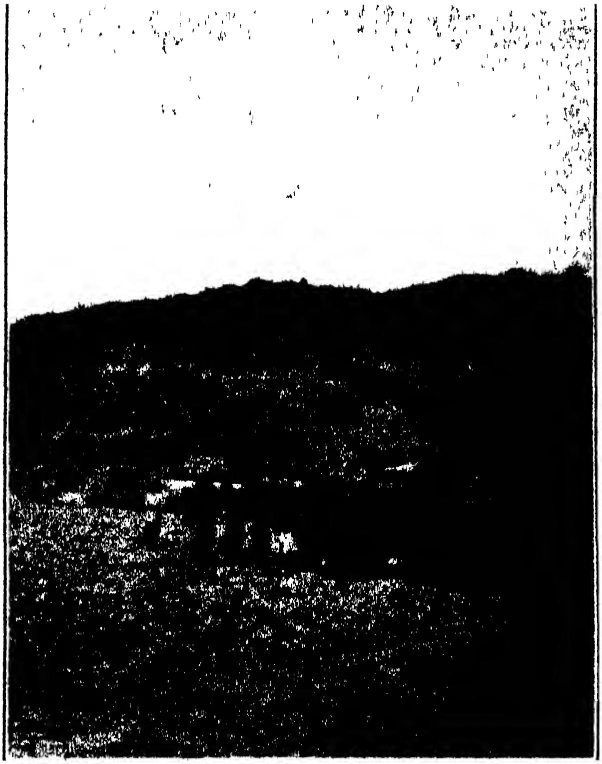
THE PUBLIC INDIAN MARKETS

No better conception of the products of the country can be obtained than at these, and none is more important than the produce and live stock market at Clisa, Bolivia, below Cochabamba on the eastern slope of the Andes. Products sold here may have come from places several days' journey distant

were paid to the government from the products of the land. Huge granaries were built for the storage of food against the time of need Physical comfort for all was sought There was nothing to long for, and it was stupid to be ambitious, for this kindly, beneficent and paternalistic form of government took care of everything.

Into this community life came Pizarro and his men in 1532 with fewer than 62 horsemen and 102 footmen The Inca kingdom had just been wrenched in twain by civil war. To Huascar, the legitimate heir, had been left the southern three fourths of the kingdom, and to Atahualpa, the illegitimate, though victor, was left the rest, with Quito as the capital. There is no need of retelling the story, so well told in Prescott's "Peru" Whether the stories of the immense treasures of gold found there are true or not, it matters little now. It is true that a handful of white men took what they wanted, murdered the men, raped the women and enslaved them all —a slavery which, in spirit, is just as real to-day as it was in the day of Pizarro.

Their long history makes their present condition especially pathetic. Although by no means clearly established, various epochs

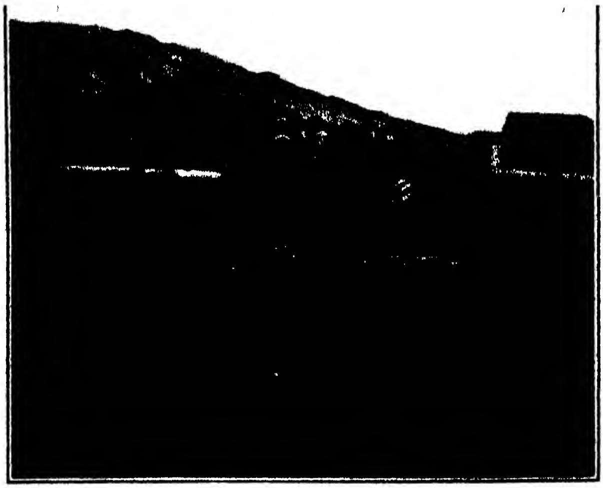


A Breakdown in the Bolivian Montaña

The automobile following along a river bed aroused considerable curiosity, especially when sufficient time elapsed for the news to spread

of culture have been worked out. Their earliest group advance is believed to begin about 200 B. C with the development in certain valleys upon the plateau. From this time up to 800 A D is given as the period of development From 800 to 1150 differentiation due to growth seems to have taken place. This is thought to be the period of the Tiahuanco culture, a period in which Peru attained its highest degree in architecture and sculpture From 1150 to 1530 is the Inca era, and during this period came about the fusion and the building up of a great empire. After this came the Spaniard and the deluge. Bishop Oldham, of South America, characterizes the condition of these people as the saddest, the most pathetic and the most hopeless of all peoples.

The complete overthrow came because the "Conquistadores" married into the royal Inca family and in one case, at least, an Inca prince married a Spanish woman of rank. The white man,



THE "TARJETA"

The people on the Bolivian plateau are hard put for fuel. The "Tarjeta," a woody mushroom growth, is brought to the railway station or town and sold by weight

in the minds of the native, thus became associated with royalty and received the same homage and respect. Even to-day in some sections, the natives, both men and women, in passing, will step out of the road and uncover in deference to the white man. With the conquest, however, nationality was destroyed and, instead of a beneficent and paternalistic government, came one of despoliation and exploitation. Organization disappeared and the fundamental arts in the activities of the people were broken up. The great dams and irrigation ditches built by the labor of thousands slowly went to decay and then became useless through neglect. Roads went out of repair and soon became impassable. The temples were sacked and desecrated and the people were forced to abandon their own religious life and take over bodily new forms of worship. This, of course, was done only outwardly, so that, even to-day, the

PREPARING POTATOES

To prepare potatoes for food in a region when the boiling point of water is low and the cost of fuel high, the Indian has solved his problem by freezing the potatoes and then working out the surplus water. Although all three women in the middle foreground were busy preparing their "chuño" the one in the center worked with such lightning activity that an exposure of a fiftieth of a second was not rapid enough to prevent blurring.

church, in many sections, is little more than a pagan institution with a Christian setting in which a weird mysticism and the strange masked processions of bacchanalian (holy) feast days form a leading part.

This miscegenation from the top down has gone on apace so that to-day there is absolutely no way of distinguishing among the native-born which are pure-bloods, either white or Indian. Such a classification, nevertheless, would be meaningless, for the difference recognized locally is not one of blood, but one of position, rank, or opportunity. There is a general recognition, however, of three classes: (1) the "gente" or gentry, mostly white who live to be served; (2) the "mestizos" or "cholos," the mixed bloods or artisan group; and (3) the "indios" or "indiada," the agriculturists. In Bolivia, one of the most distinctively Indian countries, the pure white population, excluding foreigners, is perhaps less than 5 per cent. The census of 1900 gave 14.64 per cent., but these figures, it must be remembered, do not give the true blood situation, but

AN INDIAN VILLAGE OF THE MONTAÑA OF PERU
There are said to be more hogs than people in the village and act as the street cleaning force

rather that of rank Of the mestizo, or mixed class, the number varies in different sections 8 13 per cent. in the department of La Paz to 51 54 per cent in Cochabamba The same census gave the Indian population as 48 42 per cent. of the total, with the highest in the department of La Paz, 75 61, where the amalgamation of the race has been the least

Their sad condition and the lack of progress are not due to laziness or lack of energy. They are extraordinarily industrious, yet get nowhere. One is impressed with the futility of their movements The amount of work done in terracing and gathering stones into heaps and walls is astounding In some hilly sections literally every available foot of soil has been preserved, walls have been built and earth carried to complete the terrace. So many stones have been carried into piles that some of the people there tell one seriously that the Indian will pile stones for no other purpose than just to make a pile. In many sections the picture that remains with the traveler is not of young, undeveloped countries but of old, overdeveloped, decadent lands The industry of the women is the most striking. They are rarely, if ever, seen in the open with idle hands. A woman may be driving a group of llamas, may have a bundle of fagots on her head, a bundle of produce on

her back, within which sits her babe, yet her hands are ever twisting the spinning spool. Neither is it a slow, leisurely walk, but ever a little toddle or dog trot with little movement of the body except of the hands and from the hips down Occasionally a young man may be seen spinning, also.

Their industry, however, is of little avail to their good, for the Indian, in general, is considered only as a part of the soil He is a gift of nature like the plants that grow on it If he has a wife and children they also form a part of the landowner's man-power If the Indian happens to have sheep or llamas or chickens, these also may be commandeered by the "patron" He has few or no rights in court The woman's lot is especially hard, and morality, as we know it, scarcely exists Women too old and girls too young to bear children, from all outward appearances, have suckling babes at their breasts An American doctor in Lima who knows the interior was emphatic in his statement that fully 80 per cent of the children born succumb the first two years

The Indian's life is without hope "Whatever is is a necessity," seems to be the philosophy, if there is one Whatever is custom is also a necessity. He knows that his fathers lived exactly as he does, his burden may be a little heavier, but there is still "chicha" to drink If there is any thinking it is at once dulled by the chewing of the coca leaves If there is no food the coca again supplies the need The priest, keeping close to his traditions, has assured the Indian of the church's divine mission, and has imbued his mind with the thought that he was made to serve his masters. In his superstition he must pay to save himself from perdition. He, therefore, is kept in debt both to the "patron" for "chicha" and coca, to the church for prayers, and, in time, looks upon debt as a matter of course. The church has a great appeal because of its feasts and its imagery, and could remake the life of the Indian if the priests would Concepts of fatherhood and love, righteousness and justice can have no meaning so long as such things are outside the pale of his experience. But an image of the virgin or a saint, in church or carried along the country road, is reverenced most pathetically. To see an old barefoot man or woman in tatters kneeling before some shrine, oblivious to the world about, talking and gesticulating as the tears roll down the cheeks, is a picture not soon forgotten.

Education, seemingly, is the only thing that can save the race, and, for that matter, the plateau nations. The Indian has the ability, but hope has been shut off for so long that only the exceptional one rises above his environment. There have been Indians at the head of affairs in Peru and Bolivia. Those that

have risen have had chances of which others have not known. However, the vital thing is not the exceptional one that rises but the mass that lives without vision The problem of education is not a simple one. In a country where the white lose caste by associating with the Indian, education can not sift from the top down. On the other hand, if education must come up through the Indians themselves, how can it get started? This is a most serious problem. The few teachers outside of the leading centers are rarely competent, although for the most part very serious-minded and anxious to learn. Few of them even know the multiplication table or have the other rudiments Outside a few cities, there are no schoolhouses worthy the name, and the governments are months in arrears in the meager salaries of the teachers.

Surely a nation can not prosper where fully 90 per cent. of the people are considered of an inferior order by the ruling few Democracy can not exist where public sentiment is unknown and where a leading official in a medium-sized town can not grasp the meaning of the phrase "public opinion" At present in many sections of the plateau there is no public sentiment, for where only an elect few can read, newspapers are shorn of their power; and the pulpits, the great disseminators and crystallizers of public opinion in this country, are unknown in Latin-America as such. The church, moreover, shows little or no interest in social betterment. In many sections, however, times are changing and there seems to be a growing consciousness of injustice and at the same time of power. In the larger centers local uprisings of the "indiada" occur with more or less frequency and are put down as regularly by the police force, from the same class, in the employ of the government of the few

The hope of the plateau nations undoubtedly lies in the education of the mass of the people. Dr Tello,[4] a Peruvian Indian, educated at Harvard, believes.

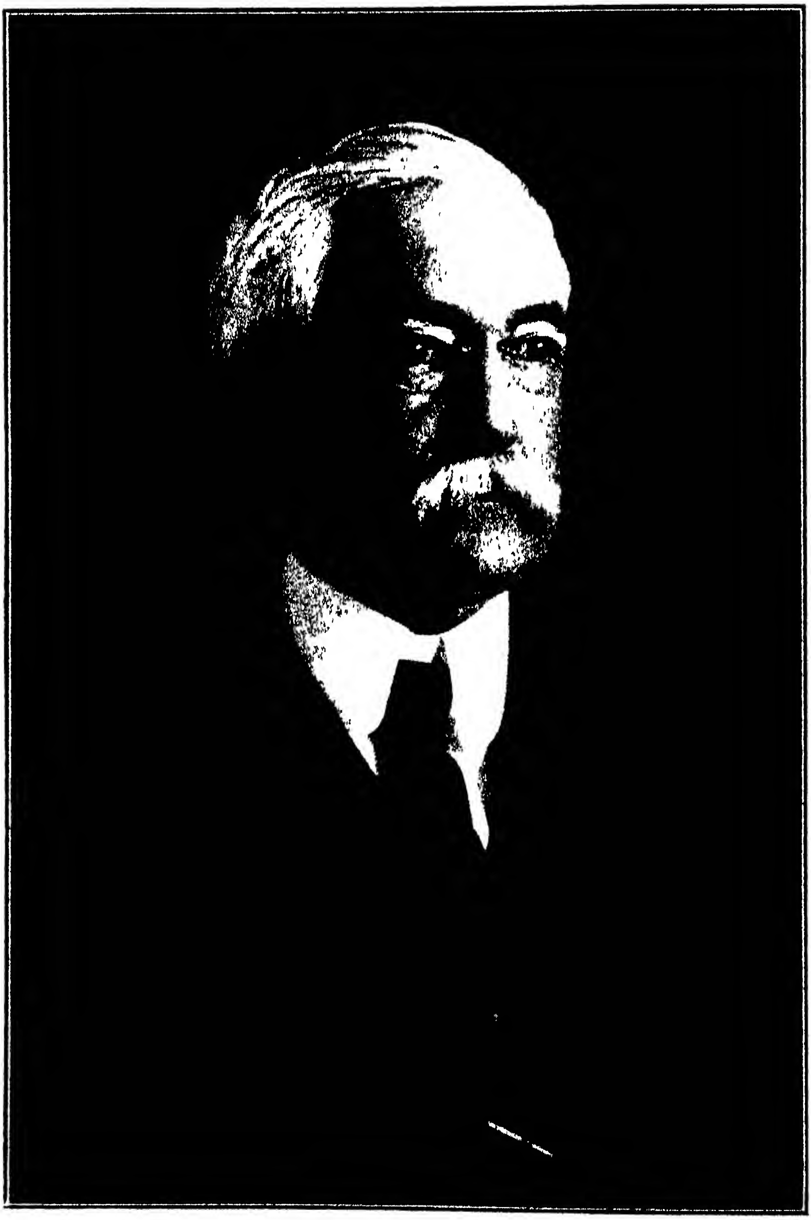
> Our present Hispanic-Peruvian civilization can be erected only on the aboriginal pedestal; and it can not stand firm and endure, if it does not completely adapt itself to the environment; if we do not seek to utilize our own resources, to discover the secrets and marvels of our nature, to admire the labor of our ancestors, to glorify the generations that have lived on our soil, wherein are preserved their ashes, and whence they drew their nourishment, and which they defended and used throughout many centuries. The present generation must revive the past and garner from it whatsoever can make it glorious.

Education can build a nation, but who will build the schools, furnish the texts or supply well-trained teachers? Surely the governments are not now in a position to do it. Who will break the in-

[4] Julio Tello, "Prehistoric Peru," *Inter-America* (April, 1922), pp. 238–250.

difference of the native and build up incentives? The church could if it were so minded. Who can take away the deadening coca which dulls the gnawing hunger and deadens the sensibilities to suffering, or the "chicha" and "aquardiente" which change, for the time being, a sordid world into a carefree one? Education can do it, yet the Indian may have to sing for a long time as in this verse translated from a Quechua poem:

To shed a tear my heart was loath,
Bitter as forgotten troth,
None came to wipe my tear away
To drink it was the only way.



ROBERT SIMPSON WOODWARD

President of the Carnegie Institution of Washington from 1905 to 1920 and previously, for twenty two years, professor of mathematical physics at Columbia University, who died in Washington, on June 29, at the age of seventy-five years.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

THE AMERICAN INVASION OF AUSTRALIA BY CACTUS

Cactus is an American invention and a most ingenious contrivance for living in an arid land. Its thick stalks enable it, like the camel, to go long without water and their small surface prevents loss of water by evaporation. Its spines protect it from being eaten even where food is scarce.

Previous to the visit of C. Columbus to this country, the entire cactus family was exclusively American. Notwithstanding this fact, the cactus continues to be put into scenes of biblical life by painters, movie directors and writers. For instance, Donn Byrne plants cactus in a recent rewrite of the Gospel story.

But once America was opened to the world, the cactus spread and now is to be found in regions as remote as those reached by our sewing machines and phonographs and kerosene, but is not so popular. There being no patent on this American invention, local cactus plants have sprung up in various places that outstrip the original in production.

In Australia more than twice as much land is now occupied with the growing of prickly-pear than with all other crops put together. The latest estimate of the area infested or invested by the pest is put at 40,000,000 to 45,000,000 acres. This is larger than old England, larger than our Georgia. The invasion is still advancing and Queensland alone is losing usable land at the rate of over a million acres a year. And Australia can not afford to lose much land, for, although on the map its area is as great as that of the United States, so much of it is desert that it can never be expected to support more than a fifth of our population.

The prickly-pear was first carried to Australia in 1788 to serve as food for the cochineal insect, which had been brought from South America in the hope of starting a thriving industry in the dye stuff. The insect and the industry failed to thrive, but the prickly-pear did. It grew so well that certain squatters (a squatter in the Australian language is the same as a rancher in the American) took cuttings into the interior to plant cactus hedges around their stations (ranches). The hedges grew so well that in the course of time they covered all the land and the stations had to be abandoned.

The pest was introduced into Queensland by a country gentleman who on a trip to Sydney in 1858 was so much interested in this curious plant that he procured a joint and carried it carefully home in his saddlebag some four hundred miles. He planted it reverently in a choice spot of his garden and diligently tended it. Finally, the growth of two new branches proved that the transplantation was a success, and the proud owner was able to eat of its fruit. In fact the transplantation was more successful than any one had anticipated, and in 1921 the Queenslanders spent $390,000 trying to eradicate the prickly-pear, and yet they are losing ground.

The public land infected by the cactus can not be sold. It can not be given away. It can not even be given away with a bonus. The govern-

ment has offered a bonus as high as $20 an acre to any one who would take the land and clear it, but could not dispose of it at that. Land within twenty miles of a railroad has been offered free in lots of a thousand or two thousand acres on condition that it be freed from cactus within ten years, but there were no takers.

In America where the prickly-pear has been so long acclimated it is an interesting and comparatively innocent plant, though uncomfortable to those who come too close to it. It contributes a picturesque feature to an otherwise monotonous landscape and bears a delicious fruit for those who like it. But in the fresh fields and pastures new of Australia it flourishes better than on its native heath. The individual clumps measure ten to thirty yards in circumference and often stand so close as to be hog-tight. Surveying parties have to chop a path through it in places. When it is cut off the crop weighs 700 to 1,000 tons per acre. In New South Wales where four million acres are more or less infected the annual loss is estimated at $2,500,000.

How to get rid of the prickly pear, or at least check its further spread, has been the subject of an investigation of a commission of the commonwealth under the scientific control of Dr. T. H. Johnston, of the University of Adelaide. His conclusion, as expressed to the Wellington meeting of the Australasian Association for the Advancement of Science, is that chemical means of extirpation, such as poisoning by arsenic, are so expensive as to be prohibitive, and that there is no probability that cactus can be turned into a source of income, as has been the case with another pest innocently introduced, the rabbit. He regards the prickly-pear as of little value as fodder for sheep or cattle. It has been found in New Mexico and South Africa that the juice of the fruit can be fermented and made into alcohol, but this, he concludes, could never be made profitable. There remains only the biological method of attack and Dr. Johnston proposes to draft into the warfare various sorts of bugs and worms, beetles and weevils, bacteria and fungi, that have been found preying upon the cactus in any part of the world. These, the natural enemies of the pestiferous plant, would attack it at all points, root, stem, segment and fruit, and by keeping up the conflict day and night may accomplish what man can not do directly.

It is an ingenious plan of campaign, but there is always the danger that the insect or parasite introduced to attack the cactus may find the crops as good or better feeding, and so the allies desert to the side of the foe. The lesson of it is that a nation can not be too careful what sort of immigrants it admits, be they vegetable, animal or human.

FREE AIR

WIND was the first mechanical motive power that man learned to use. Probably it was discovered by some savage of a long gone age who made a sail of his blanket and a mast of himself, like Fayaway in Melville's "Typee," and so found his canoe propelled across the lake without the labor of rowing. From this simple craft was descended the skiff, the schooner and the full-rigged ship.

A few hundred years ago some one, perhaps a Dutchman, discovered that it was possible to attach the sails to a stationary post, instead of to a movable mast, and so make a windmill that would grind his corn. In England a windmill is mentioned as early as 1191. In France we can go back to a date of 1346, for we are told that Edward III viewed the battle of Cressy from a windmill.

But when the more convenient and reliable coal came in the local windmill and waterwheel went out, and the steamship replaced the sailboat. At the present time, little use is made of wind power, either on sea or land, although "free air" is to be had anywhere. But I venture to predict that sometime in the future— a wise prophet is indefinite as to date—the inexhaustible reservoir of kinetic energy in the moving atmosphere will be drawn upon for motive power to supplement or replace our stores of fossil fuel, now being rapidly exhausted.

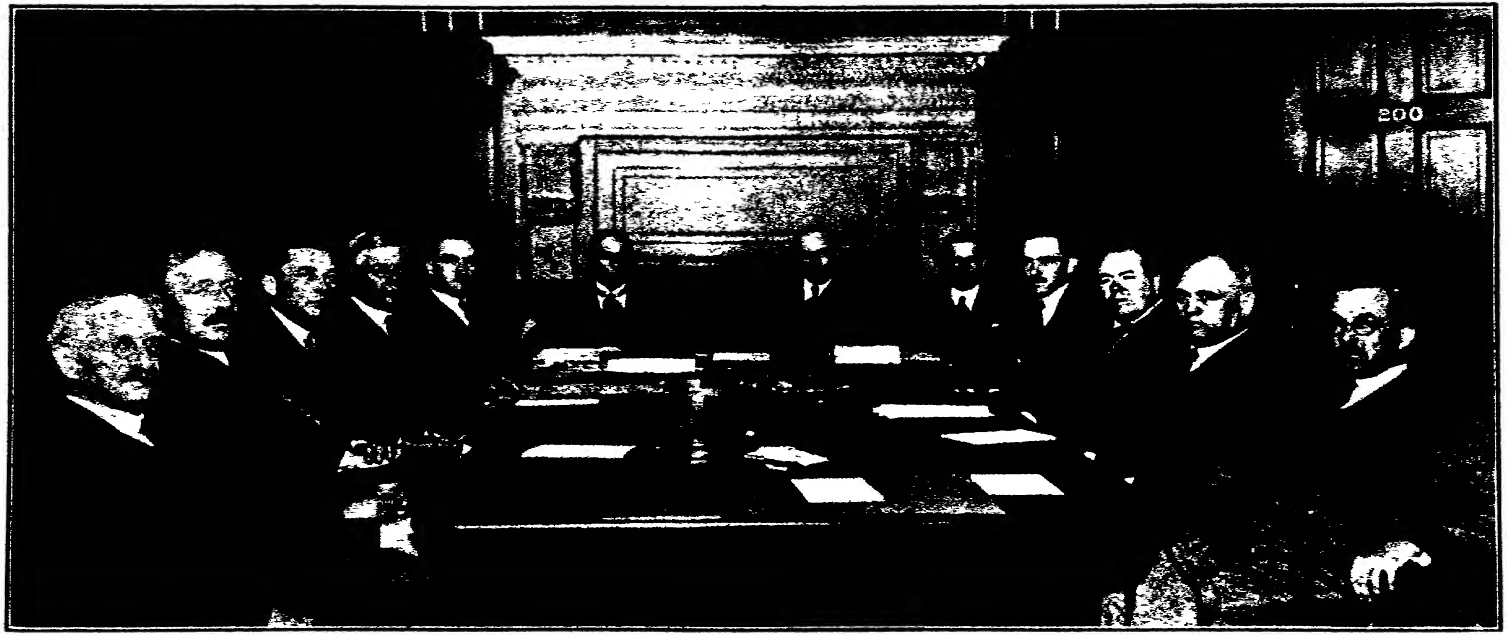
I imagine that sails will once again be seen upon the sea, more frequently than they ever have been before, and that landlubbers too will eventually find that they can not afford to neglect this freely flowing energy. It amounts to considerable if you figure it out Suppose for instance that you live in one of those states where the velocity of the wind averages roughly 11 miles an hour throughout the year. This velocity of air represents about one tenth of a horse power per square meter at right angles to the wind. A layer of this wind, 66 feet deep and 425 miles from side to side, would represent 1,368,000 horse power.

I do not wish, however, to be understood as saying that a farmer could put up a row of windmills and extract all the energy from the passing breeze. This would, of course, mean stopping the wind entirely, and would result in an uncomfortable accumulation of dead air on the farm that would be difficult to dispose of. And his neighbor next beyond would not be able to raise the wind.

But it does seem to me that we might well utilize even now a little more than we do of this vagrant wealth. It is purely a practical problem of collecting and storing and delivering scattered and variable quantities of energy, the same problem as we shall have to solve if we are to utilize the wasted power of our minor streams and fluctuating tides.

At present the most practical way of storing wind power is by employing it to pump up water into a tank so as to use the gravitational force of its fall when wanted. But this method is of limited application. A more promising scheme is to use the surplus wind power in charging a storage battery from which electrical currents can be drawn as needed. But on account of the expense and difficulty of keeping up an extensive storage battery system this has not yet come into common use, although there are several practical wind-electric outfits now being manufactured in this country. Another and more ambitious plan of solving the problem is proposed by J. B. S. Haldane, of Cambridge, who has the most far-reaching imagination of any biologist since Wells grew up. In his new book, "Daedalus" he foresees the time when England will be covered with rows of metallic windmills running dynamos. The surplus power of these will be used for decomposing water into hydrogen and oxygen, which will be liquefied and stored underground in great jacketed reservoirs. In times of calm the two gases will be again combined and since they produce the most heat of any chemical reaction, they would be used in gas engines. But even Mr. Haldane puts this four hundred years in the future.

The modern wind motor is more efficient than the steam engine as an energy transformer since it can utilize some 15 per cent. of the power of the wind that reaches it, while an ordinary steam engine does not ordinarily utilize more than 13 per cent. of the energy of the coal. But the water turbine is far more economical than either, since it can make available 70 per cent. or more of the energy it receives. In experiments made some years ago at the Agricultural Experiment Station of North Dakota,



ARCHEOLOGICAL CONFERENCE AT THE CARNEGIE INSTITUTION OF WASHINGTON

Conference of leading archeologists and anthropologists of the United States, with Dr Manuel Gamio director of the Bureau of Anthropology of Mexico, which considered the explorations of the Carnegie Institution in Yucatan. From left to right are. Professor Byron Cummings, University of Arizona; Professor A. V. Kidder, Phillips Academy, Andover, Mass; Clarence L. Hay, American Museum of Natural History; Dr. H. J. Spinden, Harvard University; Neil M Judd, U. S. National Museum Dr Manuel Gamio; Professor Eugene M. Gomez Maillefert, Buraeu of Anthropology of Mexico. Dr J. C. Merriam, President of the Carnegie Institution. Dr S G Morley, Carnegie Institution; Earl H. Morris, Carnegie Institution; Dr. Mitchel Carroll, George Washington University, Professor A M Tozzer, Harvard University; Professor R. V. D. Magoffin, president of the Archeological Institute of America

it was found that the cost of electricity from a windmill in that state was only about a third of its cost from a gasoline engine, and that the initial expense of the two outfits was practically equal. The Agricultural Experiment Station of Wisconsin found that the wind in that state could be depended upon to blow at the rate of nine miles an hour or more for five thousand hours in the year. This is sufficient to run a windmill, which therefore would be working 14.3 hours a day on the average. A 16-foot geared windmill would furnish two horse-power for ten hours a day. The Germans are experimenting on gigantic wind power plants to replace the coal they lost through the war, and it is claimed that these can produce current at a cost of less than a cent per kilo-watt-hour.

It is to be hoped that some day we may be able to get our power from the clean and open air rather than from the dark and dirty mine. A row of revolving vanes on a hilltop is certainly more picturesque than an oil derrick or coal dump. There would also be gain from a sociological as well as from an esthetic standpoint, since wind power is to be had almost everywhere and can not be monopolized like coal and oil. It is a decentralized source of power, and it is inexhaustible.

CONTAGIOUS HEALTH

WHEN Bob Ingersoll was lecturing on "The Mistakes of Moses," he was asked sarcastically if he thought he could do any better if he were running the universe. He replied "Yes," and when challenged to specify in what particular he could improve on the present administration he answered that if he were the Almighty he would make health contagious instead of disease.

This, like other of his witty retorts, will not stand close scrutiny. In fact, recent researches indicate that the proposed improvement is already in existence and has been for ages. As we now know the microbes are not all enemies of man. Some are his active allies, and they carry on warfare in his defense in much the same way as the disease-producing kinds do against him.

A French biologist, d'Herelle, discovered in 1917 that bacteria are preyed upon by something yet smaller than themselves, something too small to be seen with any microscope or to be filtered out from a fluid, for they will pass even through the pores of porcelain. "Bacteriophages," he calls them—"bacteria-eaters." They are so minute that it would seem that they must belong to the field of chemistry rather than biology, yet they grow and propagate and maintain a definite individuality like living creatures. They are normally present in our digestive tube and protect us by breaking down and dissolving inimical bacteria. The greater the number of the invading hosts, the faster the bacteriophages multiply and the fiercer they become in fight, until finally they have overcome the infection. They may then in the flush of their victory carry their campaign into the enemy's country and cure others of the community. The sick persons who have been cured thus become carriers of the cure and centers of healing infection, so starting an epidemic of health. As d'Herelle says in his new book "Defenses of the Organism":

> A sick animal propagates the disease. An animal in a state of active resistance propagates immunity. These few words sum up the whole history of epidemics.

Dr. d'Herelle may be over-sanguine in thinking that he has seized the whole secret of epidemics, but his discoveries are in line with the modern

Wide World Photos

"PALE FACE" INDIANS FROM PANAMA

Three "White Indian" children brought to New York by Richard O. Marsh from the little known San Blas Country of Panama, photographed at their New York hotel. The two boys and a girl, ranging in age from ten to sixteen, have golden white hair and eyebrows, hazel eyes and pink skin. Their parents are said to be copper colored. There are said to be hundreds of blond Indians in the region.

methods of medical practice, which is to enlist the aid of bacteria in our defense against bacteria and to promote civil war in the Kingdom of the Protozoa. We have already in our midst an army of defenders in the form of white corpuscles of the blood, and these may be multiplied and encouraged to greater exertions by medical means. We may counteract a toxin with an antitoxin. We may, as Metchnikoff advised, colonize the colon with the benign bacteria that produce lactic acid, in place of those that produce poisons. We may infest parasites with minor parasites. We may set the ultramicrobe to catch the microbe.

In this way we may hope to stave off the day when we shall fall victim to the innumerable hosts of invisible foes that continually beset us, though, so far, they have in the end come out conquerors in every case. "A bacillus less than one five thousandths of an inch in length, multiplies, under normal conditions, at a rate that would cause the offspring of a single individual to fill the ocean to the depth of a mile in five days." The cholera bacillus doubles in numbers every twenty minutes How can a clumsy creature like man, who requires twenty years to grow up, ever hope to compete with such a rapid multiplier? Yet somehow he does manage to overcome the cholera and keep it under control He even begins to believe that he may in the course of time completely exterminate those disease germs which must live on and in man, for once every patient were cured or secluded these would vanish from the earth, never to reappear. So man by the aid of science may in time vanquish the earth-born myrmidons of his arch enemy, Beelzebub, God of Flies and Vermin.

EDUCATION ESCAPING FROM THE SCHOOLROOM

ONCE upon a time a country school teacher rang her bell after recess but none of the children came in She went outdoors to see what was the matter and found them all gathered along the roadside. "Oh, teacher," cried the children, "Can't we stay out a minute longer? There is a circus coming by and we want to see the elephant." The teacher hesitated a moment but she was a conscientious woman and knew her duty. "No, children," she said, "Work must come before play." So she gathered them all in and shut the door and set them at their reading lesson, which was on "The elephant, its appearance and habits."

Now like all fables this is capable of being interpreted in various ways. It may be argued that moral training is of greater value than informational acquirement, that it was more important that the children should acquire the habit of obedience and be able to resist the temptation to distraction of attention by passing events than that they should learn how an elephant looked. Put to the pragmatic test who of us can say that his conduct or happiness in life has been materially affected by his knowledge that the elephant is distinguished by the possession of two tusks and a trunk?

But if we consider the question from a purely pedagogical point of view and assume that the teacher's duty was that prescribed by the curriculum, namely, the imparting of information about the elephant, then we must admit that she did not adopt the best plan for the purpose, that she adhered too closely to methodology, that she failed to recognize that there are different ways of getting at the same thing, in short, that she allowed the means to obscure the end, which is a common fault of ordinary people as well as of school teachers.

Science has produced so many new ideas in recent years that they have burst through the walls of schoolroom and laboratory and have escaped into the open. No professor can now maintain a monopoly of his own profession. He will often meet with men who know as much as he does about his science and yet have no title in front of their names nor degrees trailing after them. Day by day in every way it is getting harder and harder for the teacher to keep ahead of his students. More and more the students are learning science out of school. I fancy it would have taken many years for the new theories of electricity to have been incorporated into the common mind if the radio had not come along to help out the teacher. But now we have kids talking about electron streams and metric wave lengths as they skate along the streets And they know what they are talking about as they can demonstrate by making radio receivers that work.

I fancy more physics has been taught to the present generation by the automobile than by the professors The automobile is autocratic in its methods It has the habit of stopping suddenly in the middle of the highway or on a railroad crossing and giving the chauffeur a quiz on the chemistry of combustion or the laws of mechanics And the chauffeur is not allowed to pass until he has given a practical demonstration of his knowledge. Seventy per cent. of book learning will not suffice.

This spread of science to the outside world is scary to the teacher who is secretly unsure of his own knowledge and therefore prefers to cling closely to his text-book But the competent and confident teacher will welcome the new opportunities it offers for extending his influence outside his class room and awakening more interest within.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1924

HEREDITY AND ENVIRONMENT

By Professor H. S. JENNINGS

THE JOHNS HOPKINS UNIVERSITY

KNOWLEDGE of heredity has changed fundamentally in the past few years; in consequence the relations of environment to heredity have come into a new light. What has gotten into the popular consciousness as Mendelism—still presented in the conventional biological gospels—has become grotesquely inadequate and misleading; its seeming implications as to the trivial rôle of the environment have become null and void.

What happens in any object—a piece of steel, a piece of ice, a machine, an organism—depends on the one hand upon the material of which it is composed; on the other hand upon the conditions in which it is found. Under the same conditions objects of different material behave diversely; under diverse conditions objects of the same material behave diversely. Anything whatever that happens in any object has to be accounted for by taking into consideration both these things. Neither the material constitution alone, nor the conditions alone, will account for any event whatever; it is always the combination that has to be considered.

Organisms are like other objects in this respect; what they do or become depends both on what they are made of, and on the conditions surrounding them. The dependence on what they are originally made of we call heredity. But no single thing that the organism does depends alone on heredity or alone on environment; always both have to be taken into account.

What an organism is first composed of comes directly from its parents; this is the reason why dependence on that composition has been called heredity. But this habit of speech has led to conceiving heredity as something in itself, an entity, a "force," something that itself does things—an error that has induced clouds of misconception. Possibly we should be better off with no such concept as heredity: then analysis would be correctly directed toward under-

standing, in organisms as in other things, in what ways there is dependence on the stuff they are made of: in what ways on the conditions in which that stuff is found.

As to the dependence on the stuff that they are made of, research has shown that the substances passed from parent to offspring, giving rise to the phenomena of inheritance, are a great number of discrete packets of diverse chemicals, imbedded in a less diversified mass of material. The masses formed by the grouping of these packets are visible under the microscope as the chromosomes The number of different kinds of packets that go into the beginning of any individual is very great, running into the hundreds or thousands. They are not massed in a haphazard way, but are arranged in a definite manner; so that the young organism is like a well-organized chemical laboratory with many reagents so arranged in containers as to react with each other in an orderly way, producing a definite and harmonious result.

Development we know consists in this orderly interaction of these substances—with each other, with the rest of the cell body, or cytoplasm; and with the oxygen, food and other chemicals brought into the cell from outside; all under the influence of the physical agents of the environment. The final result—what the individual becomes—is dependent upon all these things; a change in any of them may change the result.

The disposition of the chemical packets, or genes, is known to be at the beginning that of a double serial arrangement, like a pair of strings of beads; each chemical has its precise and practically invariable place in the series. For each packet in one of the two strings there is a corresponding packet in the other, so that the whole forms a set of pairs of packets. The two corresponding packets of one pair may both contain the same chemical. More commonly, perhaps, they contain chemicals somewhat diverse, though of related character; every individual has a great number of such pairs with diverse chemicals in the two packets.

When the organism becomes a parent, these sets of packets are distributed to the offspring according to a simple plan. The laws of heredity are in the main simply the rules of distribution of the packets. One parent gives to any particular offspring one packet only of each of its pairs. The other parent supplies the corresponding second packet of the pair, so that the offspring has again the full complement of pairs. The first of the rules of distribution discovered was the so-called Mendelian Law; it is the rule according to which the two packets belonging to the same pair are distributed. But when we take into consideration the interrelations of packets belonging to different pairs, a whole set of rules is discovered, cov-

ering the distribution of all the packets. These have been worked out in recent years: they are of equal importance with Mendel's Law. In essence all these laws are simple; any set of beads or buttons can readily be put through the same simple operations, and then they yield the same rules that we call the laws of heredity. But for genes located in different parts of the system, the rules of inheritance are somewhat diverse; and some of the genes are not paired, so that they yield a set of rules very different from those followed by the others. The only way to grasp the laws of inheritance is to arrange a set of objects in the way the genes are arranged and to put them through the simple movements followed by the genes; attempts to understand them in any other way are futile. The laws of inheritance are not immediate consequences of some fundamental physiological principle, but of the arrangement of the packets of chemicals and their method of distribution. Where the arrangement is different, there are other laws. For many kinds of reproduction, on this account, nothing resembling Mendelian inheritance occurs. But as the rules work out in most cases of biparental inheritance, every germ cell gets a different combination of these packets of chemicals from that obtained by any other, so that in consequence every individual starts out as a different combination of chemicals from every other; this makes prediction of results more hazardous in this field than is sometimes represented.

Any correct notion of the relation of environment to heredity depends on proper knowledge of how these packets of chemicals operate in producing the developed organism. This knowledge is obtained in two ways. One is by direct study under the microscope of the changes that occur during development, with experiments on the developing embryo. The other is by interchanging the different packets of chemicals and noting the consequences. In certain organisms it has become possible by proper mating and breeding to control the distribution of the packets almost as if they could be picked out and moved about by hand; this is essentially what is done by Morgan and his associates in their work on Drosophila.

Substituting one or more packets for others is found to change the characteristics of the organism produced; different sets give when they develop, even under similar environments, different physical, mental and moral peculiarities. The first precise discovery made was, essentially, that when a single one of the packets is exchanged for another, some definite later character is changed. So, changing one packet alters the color of the hair from black to red; or changes the eye color from blue to brown; or makes the organism short instead of tall; or even changes a person from a normal individual to a feeble-minded one; or the reverse. Characters changed by altering a single packet were the so-called "unit

characters" of Mendelism. These facts—the relation of single packets to particular later characteristics—gave rise to a general doctrine, a philosophy, of heredity and development—a doctrine which has had and still has a very great influence on general views of life. It is to this doctrine that the prevailing ideas as to the relation of heredity and environment, as to the relative powerlessness of environment, are due. But it has turned out to be a completely mistaken one. This fact has not come to general consciousness: the doctrine continues to be a source of mystification and error. Its complete disappearance would mean a very great advance in the understanding of life.

From the fact that the "unit characters" changed when a single gene changed, it was concluded that in some ill-defined way, each characteristic was "represented" or in some way condensed and contained, in one particular gene. There was one gene for eye color, another for stature, another for feeble-mindedness, another for normal-mindedness, and so on. Every individual therefore came into the world with his characters fixed and determined. His whole outfit of characteristics was provided for him at the start; what he should be was preordained; predestination, in the present world, was an actual fact. Environment might prevent or permit the hereditary characters to develop; it could do nothing more. Heredity was everything, environment almost nothing. This doctrine of the all-might of inheritance is still proclaimed by the popularizers of biological science.

But this theory of representative particles is gone, clean gone. Advance in the knowledge of genetics has demonstrated its falsity. Its prevalence was an illustration of the adage that a little knowledge is a dangerous thing. The doctrine is dead—though as yet, like the decapitated turtle, it is not sensible of it. It is not true that particular characteristics are in any sense represented or condensed or contained in particular unit genes. Neither eye color nor tallness nor feeble-mindedness, nor any other characteristic, is a unit character in any such sense. There is indeed no such thing as a "unit character," and it would be a step in advance if that expression should disappear.

What recent investigation has shown is this: the chemicals that were in the original packages derived from the parents—the genes—interact, in complex ways, for long periods; and every later characteristic is a long-deferred and indirect product of this interaction. Into the production of any characteristic has gone the activity of hundreds of the genes, if not of all of them; and many intermediate products occur before the final one is reached. In the fruit fly at least 50 genes are known to work together to produce so simple a feature as the red color of the eye; hundreds are required to produce

normal straight wing, and so of all other characteristics. And each of the cooperating packets is necessary; if any one of the fifty is altered, the red color of the eye is not produced.

And this is what gave rise to the idea of unit characters represented by particular genes. For suppose that one parent has all the fifty packets necessary to produce the red eye, while the other has but forty-nine of them, the fiftieth containing some substance that will not work in producing red. Then this parent will not have a red eye, but perhaps a white one, although it differs from the other in but one gene. When these parents produce descendants, the red and white eyes follow in heredity the distribution of that single pair of genes of which one is altered: wherever the altered gene alone goes appears a white eye; wherever the unaltered one of the pair, a red eye. So the red color and the white color, inherited according to the Mendelian law, were called unit characters; each was supposed due to a single gene.

But actually, fifty or more genes are required to produce either, as is discovered when some other one of the fifty is changed off for an altered one. Then, although the first pair of genes is now unaltered, still the red eye does not appear. Now the eye color follows the distribution of another pair of genes.

By successively altering genes of different pairs, or by altering genes of two or more pairs in the same parents, certain general relations of the greatest significance are discovered—relations which are commonly ignored. A certain characteristic, such as the red color, may, with a given pair of parents, follow a given gene, being inherited according to a particular rule—say the "typical Mendelian" rule. In other parents it follows a different gene, and is inherited in a different way—perhaps as a "sex-linked" character. There are fifty or more separate and independent ways by which the red character can be altered, and each yields a somewhat different rule of inheritance. Or in the same individual two or more of the genes affecting color may be altered; then the color is no longer inherited as a "unit character;" its inheritance is now of the "multiple factor" type. In some cases it will follow the rules for two-factor cases; in others for three, and so on indefinitely, until the inheritance may not be distinguished from the "blending" type. Such cases are typical. The fact that in an observed instance a characteristic is inherited as a "unit character" does not show that in other cases it will be so inherited. If a characteristic is observed in a given case to be inherited as a sex-linked character, we can not be certain that it will be sex-linked in other cases. If it is recessive in some stocks, it may be dominant in others. Feeblemindedness appears to be inherited at times as a "unit character"; although nothing can be more certain than that hundreds of genes

are required to make a mind—even a feeble mind. It is not surprising that absence or alteration of some one necessary chemical should leave the mind imperfect; this is all that is shown by "unit character" inheritance. Doubtless feebleness of mind is produced in hundreds of different ways—some sorts heritable according to one set of rules, others according to other sets of rules. Color blindness in man appears in some cases to behave as a sex-linked character: this does not make it certain that in other cases it will do so. It is a general truth that, even though we have worked out the precise method of inheritance of a characteristic in a given stock, we can not be certain that this same characteristic will be inherited in that way in another stock. It all depends on which particular one or more of the hundreds of genes on which the character depends is diverse in the two parents. Heredity is not the simple, hard-and-fast thing that old-fashioned Mendelism represented it.

Further, more attentive observation has revealed that any single one of the genes affects, not one characteristic only, but many, probably the entire body. The idea of representative hereditary units, each standing for a single later characteristic, is exploded: it should be cleared completely out of the mind.

The genes then are simply chemicals that enter into a great number of complex reactions, the final upshot of which is to produce the completed body. The characters of the adult are no more present in the germ cells than is an automobile in the metallic ores out of which it is ultimately manufactured. To get the complete, normally acting organism, the proper materials are essential; but equally essential is it that they should interact properly with each other and with other things. *And the way they interact and what they produce depends on the conditions.*

This is shown to be true both through observation of the processes of interaction, in development, and through experimentation with diverse conditions. Under the microscope the set of genes—the chromosomes of the egg—are seen to go promptly to work. They suck up a quantity of material from the surrounding cytoplasm, becoming balloon-like. They transform this chemically, then give it off again into the cell body, visibly changed into something new. Diverse new substances thus formed move into different regions of the egg. By cell division some of the newly manufactured substances are passed into one cell, others into another. Thus the cells become diverse; the different structures of the body are being made. This is repeated in each cell generation, the chromosomes by interaction with the cytoplasm changing the substance of the cells, until finally nerve, muscle, bone, gland and other tissues result. But in all this interaction of the chromosomes to produce new cytoplasmic materials, the chromosomal materials—the genes

—are not themselves used up. Always a reserve portion of each chromosomal substance is saved, so that none of them are lost and their number does not decrease. And at each cell division every reserve packet is divided, half of it going to each of the two cells, where it grows to full size. So every cell of the body continues to contain the entire set of the parental chemicals, just as the egg did. The differences between the diverse cells of the body are therefore not in these substances—not in the genes they contain—but in the remaining part of the cells, the cytoplasm; these differentiations have been produced by the interaction of the genes with the cytoplasm. It is in this way that the complex adult body, with its typical pattern of structures, is produced.

In producing these structures, the genes interact, not only with each other, with the cytoplasm, with the oxygen from the surrounding medium, and with the food substances in the cytoplasm: but also, what is most striking and important, with products from the chemical processes in neighboring cells. Necessarily, then, this complicated interaction depends upon many conditions, a dependence that becomes manifest as methods of experimentation become precise. The process of development shows itself not to be stereotyped, as at first appears to be the case; it varies with changes in conditions. What any given cell shall produce, what any part of the body shall become, what the body as a whole shall become—depends not alone on what it contains—its "heredity"—but also on its relation to many other conditions; on its environment.

This is well shown in the development of our close relatives, the amphibia. The frog or salamander begins as a single cell, which divides into two. Usually one of these two produces the right half of the body, the other the left half. But this depends on the relation of the two cells to one another; separate them, and each produces an entire animal instead of half a one. Somewhat later in development the young salamander has become a sphere of many small cells, differing in different regions. Under usual conditions it is possible to predict what later structure each cell, each region of the sphere, will produce. The cells that will produce brain, eye, ear, spinal cord, skin, can be pointed out. The predicted process occurs with such regularity as to appear stereotyped.

But study shows that this is because the effective environment is usually the same for any given cell. What any cell shall become depends in fact on the conditions surrounding it: on its relation to the other cells. Development, it turns out, is a continual process of adjustment to environment. The recent brilliant work of Spemann shows that at a certain point in the developing mass of small cells (just in front of the blastopore) there begins a differentiating influence, whose further nature we do not know. This creeps from

cell to cell, forwards and sideways, determining the type of chemical processes that shall occur in each cell, in such a way as to fit and conform the structures produced by that cell to those produced by the cell differentiated just before it. In this way the whole mass of cells diversifies into the pattern of the later structures. Here the cells differentiate into spinal cord, next into medulla, next into midbrain, here at the side into eye, here into ear; still farther on into skin. But if before this has happened the disk of cells is cut off and turned sideways, or completely around, the differentiating and adjusting influence creeps through it from the same point as before, but now in a different or reversed direction, so far as the cells are concerned. The cells that were to have formed skin produce spinal cord; those that would have produced eyes may form midbrain, or skin or ear, depending on just how they are placed with reference to the spreading differentiating influence; and so of the others. Or, transplant a small piece of prospective skin to the center of the eye-producing region; it now transforms into eye instead of into skin; transplant a prospective ear to another region, and it becomes skin or spinal cord, as its place in the pattern requires. It is proved that any particular cell may become part of any one of these structures, depending on its relation to the other cells, its relation to the "pattern." There comes a time after the wave of differentiation has gone over them, when they can no longer be altered; their fate has been accomplished. But until then development is adjustment to the conditions. What part of the body a cell shall produce is not determined alone by its genes, by what it contains, but equally by the conditions surrounding it.

In later stages we know something of the nature of the cell products which help determine what other parts of the body shall become. There are a vast number of such intermediate products, necessarily produced before the adult structures can be made; some of them are the internal secretions, hormones or endocrine products which are now the reigning sensation in biology. Their production, their distribution, their action and the consequent method of development of the organism are subject in high degree to change by the surrounding conditions.

Not only what the cell within the body shall become, but what the organism as a whole shall become, is determined not alone by the hereditary materials it contains, but also by the conditions under which those materials operate. Under diverse conditions the same set of genes will produce very diverse results. It is not true that a given set of genes must produce just one set of characters and no other. It is not true that because an individual inherits the basis for a set of characteristics that he must have those characteristics. In other words, it is not necessary to have a certain char-

acteristic merely because one inherits it. It is not true that what an organism shall become is determined, foreordained, when he gets his supply of chemicals or genes in the germ cells, as the popular writers on eugenics would have us believe. The same set of genes may produce many different results, depending on the conditions under which it operates. True it is that there are limits to this; that from one set of genes under a given environment may come a result that no environment can produce from another set. But this is a matter of limitation, not of fixed and final determination; it leaves open many alternative paths. Every individual has many sets of "innate" or "hereditary" characters; the conditions under which he develops determine which set he shall bring forth. So in man, the characteristics of an educated, cultured person are as much his inherited characteristics as are any that he has.

These sweeping statements are substantiated by precisely known facts in many organisms. In that animal whose heredity is better known than is that of any other organism, the fruit fly, individuals occur with hereditary abnormalities. The abdomen is irregular, deformed; the joints between the segments are imperfect. This is sharply inherited as a sex-linked character, so that it is known to be due to a peculiarity of one of the genes in the x-chromosome. If the father has this abnormality, all his daughters inherit it, but none of his sons do so. The daughters hand it on to half their sons and half their daughters, and so on.

But the fruit flies in the laboratory usually live in moist air; this inheritance appears under those conditions. If they are hatched and live under dry conditions the abnormality doesn't appear—even in those daughters which indubitably inherit it. Clearly, it is not necessary to have a characteristic merely because one inherits it. Or more properly, characteristics are not inherited at all; what one inherits is certain material that under certain conditions will produce a particular characteristic; if those conditions are not supplied, some other characteristic is produced.

Similarly, some of the fruit flies inherit, in the usual Mendelian manner, an inconvenient tendency to produce supernumerary legs. But if those inheriting this are kept properly warmed, they do not produce these undesirable appendages. In the cold, only those individuals acquire the extra legs that have inherited the gene to which such are due; but even they need not do so, if conditions are right. In the same animal, some individuals have fewer facets in the compound eye than do others. The number of facets is found to be hereditary, in the sense that under the same conditions parents with few facets produce offspring with few facets, in the Mendelian manner. But the number also depends on the environment; individuals with the same inheritance show different numbers of facets,

depending on the temperature at which they develop. If the individual A has a certain number of facets, while B and C have a different number, the same in both, it may be found that the difference between A and B is due to inheritance, while the same difference between A and C is due to environment. Such facts are typical; differences due in one case to heredity may be due in another to environment There is no characteristic distinction between hereditary diversities and environmental diversities; whether a given instance belongs in one or the other category can be determined only by experimental analysis

Other known cases illustrate the effect of the environment in altering the totality of the organism; its entire personality, as it were. Many years ago there was discovered in Mexico a salamander that lives throughout its life in water; has a heavy, broad body, a tail flattened for swimming and external gills. In this condition it becomes mature, lays its eggs in the water; produces young that inherit its characteristics and finally dies. This continues for generation after generation. A number of these axolotls were kept for years in the zoological garden at Paris; they showed the inherited characteristics above set forth. Breeding experiments on these animals would show these characteristics to be inherited in the usual Mendelian manner.

But after years in which these were the only inherited characteristics that they were known to possess, certain different environmental conditions were brought into action, and thereupon, to the astonishment of the observers, the axolotls developed a new set of inherited characteristics, a new and diverse personality. The external gills disappeared, the body became smaller, slender and of a very different shape, the animals came out on the land and remained there, breathing air. They now became mature in this amblystoma condition, laid eggs, and produced offspring—which again, under these conditions, developed into land animals of the same sort, and this too may continue for generation after generation. The inherited characteristics are now these land characters; these are, in detail, inherited in the typical Mendelian manner.

Here we have two extremely different sets of inherited characters; which one shall appear is determined by the environment under which the organism develops. Both sets are hereditary characters; both sets are environmental characters. Any character requires for its production both an adequate stock of hereditary chemicals and an environment adequate for its production through proper interaction of these chemicals with each other and with other things.

Beyond all other organisms, man is characterized by the possession of many sets of inherited characteristics; the decision as to

which shall be produced depending on the environment. The axolotl may be compared to an uneducated man, the amblystoma to an educated one. The educated man has characteristics very diverse from those he would possess if uneducated. We say, when we think of this fact, that these are acquired characters, environmental characters, due to education. This is correct; but there is a tendency to go farther and say that these are not inherited characters, which is a mistake. The characteristics of the educated man are his native, inherited characters, just as truly as are any that he has. For all his characteristics depend on the conditions under which he develops, and would be diverse under different conditions, just as is true of the characteristics that develop under education. And the characters developed under education depend upon the hereditary materials derived from his parents, changing as these materials are altered, just as do all others. "Hereditary" has no consistent meaning other than this.[1]

Why it seems paradoxical to call the characteristics developed under education inherited, while we make no difficulty in thus designating the color of the eyes and the stature, lies in certain practical difficulties, not in any difference of principle. In the group of organisms to which man belongs there is an early period in which it is practically difficult to change effectively the conditions under which the organism develops, because it is enclosed within the mother's body, or within a resistant egg shell. So we have gotten accustomed to calling inherited those characteristics which are determined before it leaves its mother's body or the egg, while those determined later are called acquired characters. But this is an artificial distinction, based on practical considerations. In many organisms there is no such distinction into two periods; in them it is possible to alter the conditions at any period, even the earliest. And when this is done it is found that *all* the characters depend on the conditions; that such fundamental characters as the number of eyes an animal has or the position of the eyes in the body may be altered. In fish, for example, two eyes, one at each side of the middle line, form as distinctly an inherited characteristic as in man, yet fish can be subjected so early to changed conditions (as Stockard and others show) that the animal has a single median eye instead of two lateral ones; and many other equally

[1] Did not painful experience demonstrate the contrary, it would appear obviously unnecessary to emphasize that nothing in this paper has any bearing on the traditional doctrine of the "inheritance of acquired characters." This doctrine asserts, in effect, that the production of a characteristic under the influence of some specific peculiarity of the environment so changes the genes that in a later generation they produce this characteristic even in an environment that lacks the peculiarity which was originally necessary; a most doubtful thesis.

striking changes are producible by changes in the chemical environment. If the fish lived continuously in these conditions they would regularly inherit a single median eye; the two lateral eyes would be looked upon as a rare abnormality, produced by special conditions and not inherited. In truth, all characters are as certainly due to the conditions of development as to the materials of the germ cells.

If there were not practical difficulties in the way, similar fundamental changes of structure could be made in man or any of the higher animals. In these higher creatures, a time comes, before development stops, in which it *is* possible to change the conditions; that is, after what we call birth. And then it is found that changing the conditions does change the characteristics that later develop—exactly as the characteristics of the fish are changed by changing the conditions. We call this process education; if we could give the same education for many generations to a number of different human families, we should find that the characteristics resulting from education are inherited, just as are color of the eyes and form of the head; that they follow Mendelian rules, as do physical characters. Every creature has many inheritances; which one shall be realized depending on the conditions under which it develops; but man is the creature that has the greatest number of possible heritages. Or, more accurately, men and other organisms do not inherit their characteristics at all. What their parents leave them are certain packets of chemicals which under one set of conditions produce one set of characters, under other conditions produce other sets. In man, the number of diverse sets that may thus be produced is very great; although it is of course not unlimited. But what the limitations are can not be stated from general biological principles or from what we know of any other organisms; they can be discovered only by concrete studies of man himself.

Adequate recognition of these facts and principles, which appear fully established by the advance of genetics, would greatly alter some of the current discussions and attitudes on the relation of biological science to human affairs. The biologist is pained to find that the medical man resists the introduction of the concept of heredity into the domain of disease. This is because of the current fallacy that what is hereditary is certain, fixed, unchangeable. Very properly the medical man rejects that, in its application to disease. But with the recognition that to assert that a thing is hereditary signifies merely that the organism has received such a constitution as to produce it under given conditions, all such ground of objection vanishes. This does not deprive of significance recognition of the part played by heredity in medicine. The individual who may produce an inherited defect under certain condi-

tions need not produce it under others. Some individuals receive a constitution which resists disease under conditions in which others succumb to it. Some respond in one way to particular therapeutic agents, others in another way, depending on their hereditary genes. It is only against what Davenport has characterized as purely impersonal medicine that the implications of genetic science lie.

The same fallacy reappears in discussion of immigration problems. The recent immigrants show certain proportions of defective and diseased persons; and we are informed that "these deficiencies are unchangeable and heredity will pass them on to future generations." There is no warrant in the science of genetics for such a statement; under new conditions they may not appear. It is particularly in connection with racial questions in man that there has been a great throwing about of false biology. Heredity is stressed as all powerful; environment as almost powerless: a vicious fallacy, not supported by the results of investigation. We are warned not to admit to America certain peoples now differing from ourselves, on the basis of the resounding assertion that biology informs us that the environment can bring out nothing whatever but the hereditary characters. Such an assertion is perfectly empty and idle; if true it is merely by definition: anything that the environment brings out *is* hereditary, if the word hereditary has any meaning. But from this we learn nothing whatever as to what a new environment will bring out. It may bring out characteristics that have never before appeared in that race. What the race will show under the new environment can not be deduced from general biological principles. Only study of the race itself and its manner of reaction to diverse environments can give us light on this matter.

All characteristics, then, are hereditary, and all are environmental. Does not this deprive the study of the distinctive parts played by the two of all sense and value? It does not. It is of the greatest importance to know in what different ways diverse stocks respond to effectively the same environment; and how these diversities are perpetuated; what limitations the original constitution puts on what the environment can bring out; this is the study of heredity. It is equally important to know what differences appear among stock of the same original constitution under diverse environments; how great the possibilities of environmental action are with a given stock. In man, where practically every individual represents a different stock and a different environment, the matter is not one for sweeping generalizations based on general biological principles. The concepts of the hereditary and the environmental can not be employed in the absolute way now practiced; but they can be used with entire precision if they are applied, not to characteristics-in-themselves, but to the diversities between different par-

ticular concrete cases. Though stature is always dependent on both heredity and environment, the difference in stature between Mr. Jones and Mr. Smith may be purely a matter of heredity; the difference between the same Mr. Jones and Mr. Brown may be purely a matter of environment. If there is clarity as to what comparison is made, there need be no ambiguity as to what is due to heredity, what to environment.

By statistical extension, such comparison may be made for large classes. But it is essential here as elsewhere to keep in mind that we are dealing with comparisons between concrete cases, not with propositions of absolute validity. Are the differences between men due more to heredity or to environment? If we compare ourselves with our ancestors of 10,000 years ago, they are due mainly to environment— if it is correct, as generally admitted, that the fundamental constitution of the stock has not appreciably changed since that time. If the comparison is of ourselves with the Bushmen of South Africa, possibly the differences are mainly due to heredity. If the comparison is between the diverse races of Europe, or between the individual citizens of the United States, the answer is to be obtained only from a much greater amount of precise study, with critical statistical treatment, than has yet been made; and there is reason to think that it would signify little when reached, since it would be merely an average of a very great number of individual comparisons, many falling to one alternative, many to the other. Certainly the answer is not to be deduced from any alleged biological principle that the characteristics of organisms are due to heredity and not to environment.

THE ALCHEMIST[1]

By Dr. PAUL D. FOOTE

BUREAU OF STANDARDS

THE volumes on alchemy in our large libraries may be counted by the hundreds. Innumerable tracts and treatises filled with the most incomprehensible nonsense ever written have appeared in Spanish, Italian, German, Dutch, English, Arabic, Persian and Latin. The name alchemy is probably of Arabic origin, dating from the eighth century, the prefix "al" being Arabic for "the" and "chema," meaning to hide. Alchemy accordingly denotes "the hidden science." The prefix *al* occurs in many of our scientific words; alcohol, *the* burning liquid; alkali, *the* acrid substance; algebra, *the* reunion, and many others.

The scope of alchemy is a disputed question. According to the transcendental theory, it did not purport to be a science at all, but rather was concerned with man's soul. Its object was the perfection, not of material substances, but of man in the spiritual sense, a branch of mysticism in which transmutation was symbolical of the salvation of humanity.

However, most of the alchemists themselves were of the opinion that the primary object of their endeavors should be confined to the production of gold. These were the real alchemists in which we are now interested. Of such there were naturally two types. There was the knavish, corrupt alchemist, who, as Rodwell[2] says, had brains enough to perceive that his search was futile and utilized his wits to dupe more credulous people, wheedling their fortunes out of them on pretense of returning it tenfold. Modernized, these men are our successful oil-stock promoters. They abounded during the Middle Ages and became immensely wealthy by such shallow tricks as the secretion of a piece of real gold in the crucible in which the pretended transformation was taking place.

Then there were the alchemists proper, ardent, persevering

[1] Published by permission of the Director of the Bureau of Standards, Department of Commerce.

[2] Rodwell—"The Birth of Chemistry," MacMillan, 1874. This book and Redgrove's "Ancient and Modern Alchemy," Rider and Son, 1911 and 1923, contain excellent historical summaries. Several of the alchemical illustrations in the present paper were taken from these two books rather than from the original sources. Rodwell's work is especially interesting because it was written nearly fifty years ago when the atom was considered the ultimate unit; when the subject of alchemy stood in extreme disrepute.

FIG. 1. HERMES, FROM THE TEMPLE OF PSELCIS

The alchemical writers of the middle ages claimed every great man and deity of antiquity as of their number, although alchemy was practically unknown prior to the eighth century. We derive our expression "hermetically sealed" from the alchemical use of the name Hermes.

workers, who believed heart and soul that gold could be made and that by long search or diligent study of the unintelligible works of their predecessors they could discover the philosopher's stone. Poor misguided wretches—they have now become chemists, for the science, or rather art, of chemistry owes its origin to the labors of these honest men.

Honest?—only in the relativity sense, however! One needs merely to read a dozen volumes or so of their testimonials to realize that the world is growing better. For example, Magnus, of the thirteenth century, could instantly transform a winter's day into glowing summer, an accomplishment fully described by many writ-

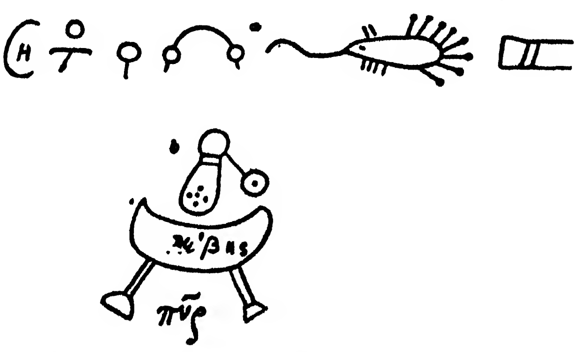
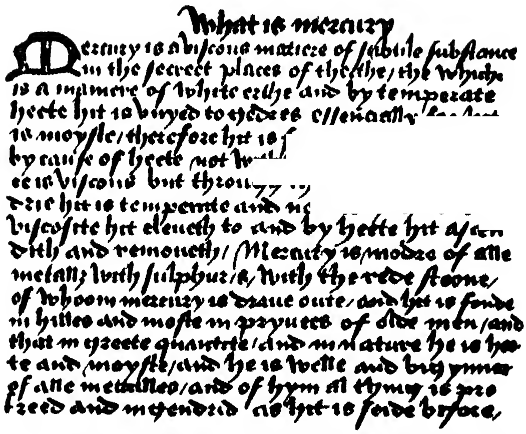


FIG. 2. AN ALEMBIC AND SYMBOLS FROM A GREEK MANUSCRIPT ON ALCHEMY



What is mercury

Mercury is a viscous mattere of subtile substance
in the secreet places of the erthe, the whiche
is a maner of white erthe and by temperate
heete hit is buyed to gederes ellenarlly
is moyste, therefore hit is
by cause of heete not w
ee is viscous but throu
erie hit is temperate and ne
viscosite hit eleueth to and by heete hit ascen
dith and remoueth / Mercury is modre of alle
metalls with sulphur, & with the rede stoone
of whom mercury is drawe oute, and hit is founde
in hilles and moste in pryuees of olde men, and
that in greete quantite / and in nature he is ho
te and moyste, and he is welle and bigynner
of alle metalles, and of hym all thyng is pro
creed and engendred as hit is seide before.

FIG. 3. ENGLISH MANUSCRIPT ON ALCHEMY DATING FROM THE FIFTEENTH CENTURY

ers and witnesses. His pupil, Thomas Aquinas, constructed a bronze statue which Magnus animated with his elixir of life. This statue was useful as a domestic servant, but was very noisy and talkative. Finally, Aquinas was forced to punish it severely with a hammer in order to continue his studies in quiet. Lulli, a contemporary, converted 50,000 pounds of base metal into the purest of gold and was employed by one of the Kings Edward to replenish the exchequer. This he did to the extent of 30 millions of dollars in synthetic gold bullion. Henry VI granted patents to alchemists on the processes involved in the manufacture of philosopher's stones. In 1404 the making of gold and silver was forbidden by

FIG. 4. AN ALCHEMIST HERMETICALLY SEALING A FLASK CONTAINING THE ELIXIR OF LIFE

Note the symbol for the sun, representing gold.

FIG 5. AN ALCHEMIST'S METHOD FOR EXPLAINING CHEMICAL REACTIONS

Note the symbols for gold (sun), silver (moon) and mercury. The lion devouring the snake represents an acid dissolving a salt

Act of Parliament To such dangerous proportions had the industry developed that the welfare of the state was threatened.

There is no doubt that the true alchemists, like the modern scientist, were much overworked individuals Paracelsus affirms that "they diligently follow their labors, sweating whole days and nights by their furnaces. They do not spend their time abroad for recreation but take delight in their laboratory. They wear leather garments with a pouch, and an apron wherewith they wipe their hands. They put their fingers amongst coals, into clay and filth, not into gold rings They are sooty and black like smiths and colliers and do not pride themselves upon clean and beautiful faces."

Let us peep into the laboratory—"a gloomy dimly lighted place full of strange vessels and furnaces, melting pots, spheres and portions of skeletons hanging from the ceiling; the floor littered with stone bottles, alembics, great parchment books covered with hieroglyphics; the bellows with its motto Spira Spera (breathe and hope); the hour glass, the astrolabe, and over all cobwebs, dust and ashes. The walls are covered with various aphorisms of the brotherhood, legends and memorials in many tongues. Look at Faust as depicted by Rembrandt for a truly alchemical interior."

Alchemy as practiced during the middle ages was the logical outgrowth of accepted philosophical thinking, which dated from the fifteenth century B. C. and was given new impulse by Aristotle in the fourth century B. C. This theory postulated four elements, earth, fire, air and water. Gradually, the terms assumed a broader meaning All incandescent objects, lightning, electrical sparks, were represented as fire. Smoke, steam, vapors and gases were called air. Water included all liquids, blood, milk, and later solu-

tions and acids, terminology now surviving in aqua fortis, aqua regia, eau de vie. Any solid was an earth, and to-day we have the *earth metals* and the *rare earths* as a result of this early usage The general idea of four elements was not disproven until a century and a half ago, when air was found to be a mixture of two (later several) gases, fire the result of intense chemical action and earth a mixture of many elementary materials

With these hypotheses, transmutation was experimentally demonstrable Fire converts water into steam or air. The alchemists therefore reasoned, plausibly enough, if water can become air why may not one metal, which was supposed to be compounded of these elements in certain proportions, be changed into another metal compounded of the same elements in a different proportion. Admitting the possibility of the process, it is not strange that men attempted to produce gold. Gold has been valued since the earliest antiquity on account of its peculiar color, its luster, its unalterability in air, and especially its rarity as compared with other commodities For its procurement, the lives of millions of men have been sacrificed in battle, in the forever distant past, praise Heaven!

It is useless to describe the methods which the alchemist employed in carrying out his prolonged attempts at transmutation. The intricate processes were subdivided into twelve groups technically known as calcination, dissolution, separation, conjunction, putrefaction, congelation, cibation, sublimation, fermentation, exaltation, multiplication and projection. A misstep at any stage in the development was fatal to the process and all the fruit of months of toil was lost in a single moment. The modern chemist or physi-

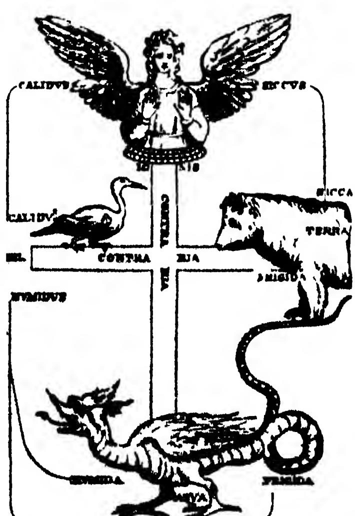


FIG. 6. AN ALCHEMICAL REPRESENTATION OF TRANSMUTATION

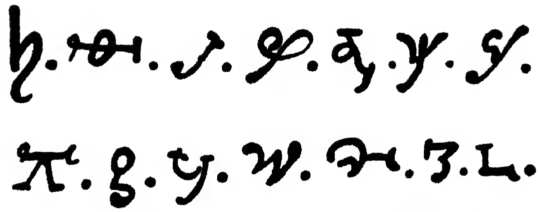


FIG. 7. SYMBOLS FOR LEAD FROM AN ITALIAN MANUSCRIPT OF THE SEVENTEENTH CENTURY

cist carries through no more elaborate experiments than those of the early alchemists.

The mystical language which these savants adopted was intended to prevent the vulgar from acquiring the results of their long-continued labors. This obscurity led to multiplication of symbols which were nearly as voluminous as those employed in astrology. In a single Italian manuscript the element mercury is represented by 22 different symbols and by 33 different names.

To illustrate how utterly nonsensical and unintelligible alchemical language could be and generally was, we quote from Paracelsus, one of the greatest alchemists of the sixteenth century:

> The life of metals is a secret fatness; . . . of salts, the spirit of aquafortis; . . . of pearls, their splendor; of marcasites and antimony, a tinging metalline spirit; . . . of arsenics, a mineral and coagulated poison. The life of all men is nothing else but an astral balsam, a balsamic impression, and a celestial invisible fire, an included air and a tinging spirit of salt. I can not name it more plainly although it is set out by many names.[3]

Figs. 1 to 7 show several typical illustrations from the early alchemical literature. The interpretation of these fanciful drawings is difficult and has proven a matter of some discussion and variance of opinion. Figs. 5 and 6 are more directly related to the transcendental or mystic aspect of the art of alchemy. Ancient books on alchemy are literally filled with allegorical pictures of this character, many of which are in color and artistically decorated.

MODERN ALCHEMY

Let us pass over a period of two hundred years and consider the subject of modern alchemy. The new developments are due to the great strides made during the past twenty years in our knowledge of atomic structure. Fig. 8 shows a photomicrograph of a copper ingot magnified 250 times. This beautiful structure is also characteristic of gold. Such photomicrographs enable the metallurgist

[3] Paracelsus, De Natura Rerum.

FIG 8. PHOTOMICROGRAPH OF COPPER, MAGNIFICATION × 250
(RAWDON AND LORENTZ)
Gold presents a similar crystal structure.

to determine whether or not a metal or alloy has the proper constitution or has been given a specified heat treatment.

Now by the aid of a supermicroscope we shall magnify a sample of gold thirty million diameters, Fig. 9. We see a space-lattice arrangement of solid spheres, each sphere an atom of the precious metal. Elastic vibration of these spheres about their positions of equilibrium accounts in a qualitative way for the specific heat of gold. The entire structure of the kinetic theory owes its success to the fact that atoms, magnified as shown, by virtue of their electric forces, do approximate hard spheres or billiard balls, especially in gases where their separation is many times that here illustrated.

We shall now use an objective of higher power and magnify a single atom 240 million times, Fig. 10. This is an atom of copper. We have a planetary system consisting of a positively charged sun

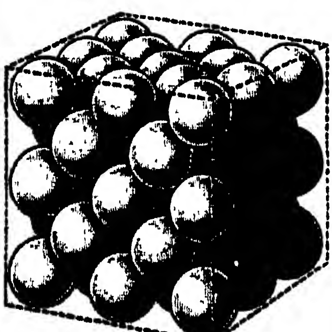


FIG. 9. GOLD MAGNIFIED THIRTY MILLION DIAMETERS
Each sphere represents an atom.

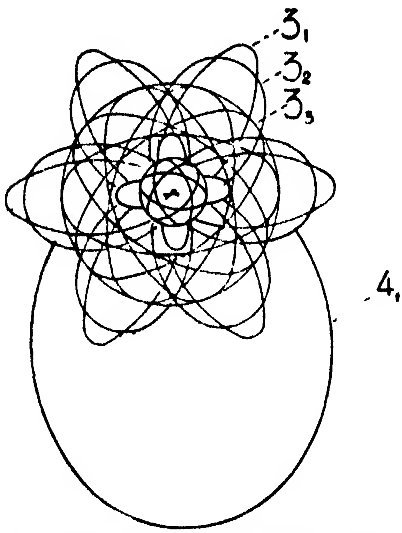


FIG. 10. AN ATOM OF COPPER MAGNIFIED 240 MILLION TIMES

There are 29 elliptical orbits each one occupied by a single electron. Gold has a similar general appearance but its inner structure is much more complicated by the presence of 50 additional orbits The original drawing and model are due to Bohr.

surrounded by revolving planets or electrons Each elliptical orbit is occupied by a single electron. Copper possesses a nucleus carrying a positive charge of 29 units and a planetary system of 29 revolving electrons Gold has a positive nucleus of 79 units with 79 electrons, each revolving in its own elliptical orbit. Nearly all the mass of any atom is contained within the nucleus. The surrounding electrons contribute practically nothing to the total atomic mass, and yet the nucleus is so small as to be scarcely representable on this scale of magnification. The electrons revolving in the outer elliptical orbits are responsible for the ordinary spectrum of an element and for its chemical and physical behavior; the electrons on the inner orbits give rise to x-ray spectra. The net positive charge on the nucleus is numerically equal to the atomic number of an element, or to the ordinal number characterizing its position in the Periodic Table; 1 for hydrogen, 2 for helium, 10 for neon, 79 for gold and 92 for uranium.

The nucleus also has a very complicated structure. The sun in the atomic solar system is itself a planetary system built up of hydrogen suns, helium suns and electrons. Our microscope has not sufficient resolving power to clearly indicate the configurations which these three units assume when grouped together to form the nucleus of a heavy atom such as gold. Fig. 11 shows the sun of the helium atom magnified four thousand billion diameters. It con-

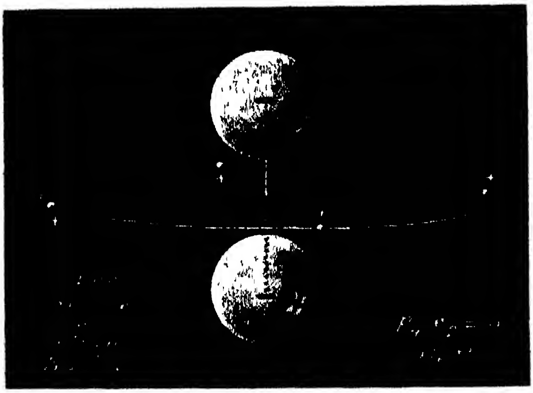


FIG 11. THE SUN OR NUCLEUS OF A HELIUM ATOM MAGNIFIED 4,000 BILLION DIAMETERS (Drawn by H. D. Hubbard)

sists of four minute hydrogen nuclei and two relatively large electrons. Now the sun in an atom of gold may have 49 of these helium suns, one extra hydrogen sun and 20 electrons, all packed in the space of 30 billionth billionth billionth billionth of a cubic centimeter. Alchemy is concerned with reactions involving the disintegration of these minute nuclear suns.

Nature has always performed transmutations of the elements, but these were not noticed by scientists until 1896, when the discovery of radioactivity was made. Since then we have isolated about 40 radioactive atomic species each with well-known physical and chemical properties and each with a definite and characteristic kind of radioactivity. All in this group have atomic weights lying between about 200 and 238, and hence are our heaviest elements.

One of these elements is radium, which chemically and physically resembles barium and which belongs to the second Group of the Periodic Table. This atom possesses a planetary system of 88 electrons revolving about a complicated nucleus having a net positive charge of 88 units, as shown in Fig. 12. The nucleus is located at the center of the configuration, but is too small to appear in the figure. Now every once in a while a radium atom spontaneously ejects a particle from its nuclear structure This particle, which is known as an α-ray, is emitted with a velocity of about 10,000 miles per second, or twenty thousand times greater than that of the swiftest rifle bullet. Mass for mass, its energy of motion is four hundred million times greater than that of the bullet.

The atom of the metal radium which emitted this α-particle is no longer radium.[4] It has been transmuted into an atom of a gas

[4] The "mortality" of radium atoms is 4 "deaths" per 10,000 per year; that of human beings is around 140.

called niton or radium emanation, belonging to the family of rare gases, helium, neon, argon, etc. Niton consists of a nuclear structure containing a net positive charge of 86 units surrounded by 86 planetary electrons. The schematic representation of these orbits is similar to that of Fig. 12 except the two orbits extending to the extreme upper right and left hand corners of the illustration are absent. The real difference between neon and radium, however, is due to the transformation which has taken place in the nuclear structure. One may remove the two protruding orbits (the valence electrons) of radium without producing niton. This is possible in a simple chemical reaction.

The atoms of the gas niton similarly explode once in a while and each atom emits an α-particle from its nucleus with a definite velocity, while the parent gaseous atom is transmuted into an atom of a new material, a solid, having the chemical properties of an element in the sixth group of the Periodic Table. And so the process continues as will appear later.

If these α-particles are allowed to strike a photographic plate, fogging is produced. If they fall on a fluorescent screen, such as zinc sulphide, they give rise to luminosity or scintillations, an effect which may be seen in the spinthariscope. If they pass through a gas they are capable of rendering the gas electrically conducting. It is because of these properties that the α-particle may be easily studied. In this way we have determined the following facts:

(1) By observing the deflection of the α-particles in electric and magnetic fields we learn that the particle carries a positive charge, and the velocity with which the particle is projected is characteristic of the parent atom.

(2) By counting the scintillations produced by a definite amount of radioactive material upon a screen of a definite size we

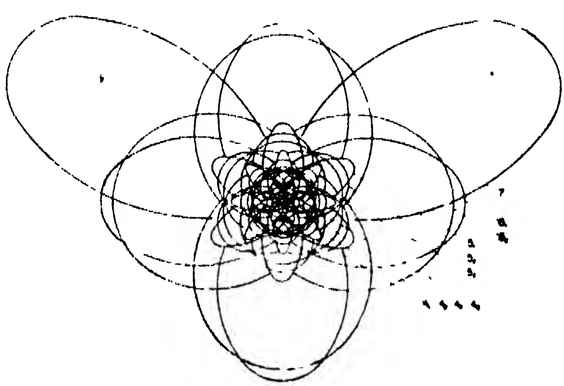


FIG. 12. AN ATOM OF RADIUM MAGNIFIED 140 MILLION DIAMETERS
There are 88 elliptical orbits each one occupied by a single electron.
Original drawing and model are due to Bohr.

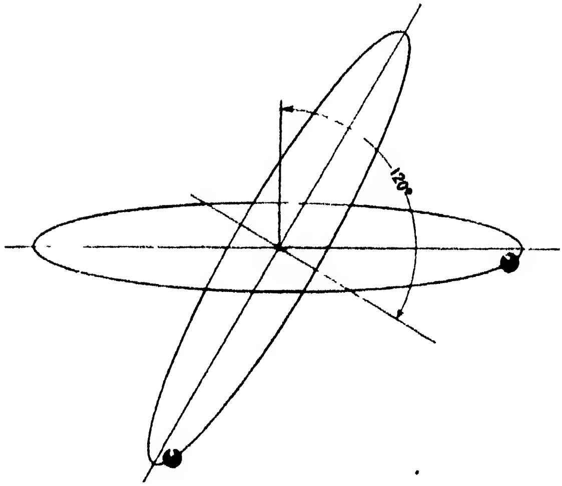


FIG 13. KEMBLE BOHR MODEL FOR THE HELIUM ATOM MAGNIFIED ONE BILLION DIAMETERS

The small dot in the center is the α-particle of which Fig. 11 is a magnified picture.

are able to determine the number of α-particles which the material emits per second.

(3) By collecting these particles in a suitable electrical apparatus we may measure their total charge and hence the charge on a single α-particle. This is found to be two units of positive electricity.

(4) Knowing the charge, it is possible to determine the mass of the α-particle by measuring its deflection in electric and magnetic fields. The mass so observed is 4 relative to oxygen 16. That is, the mass of an α-particle is the same as the mass of a helium atom.

(5) The α-particle is capable of passing through very thin glass. If a quantity of niton gas is compressed and sealed in a thin glass bulb and this bulb is placed inside a larger evacuated and sealed bulb, having heavy walls, it is found that the pressure in the outer bulb gradually increases as the α-particles penetrate into the space. After a few days enough gas accumulates so that an electrical discharge may be passed through it. The spectrum reveals the newly formed gas as pure helium. Hence not only does the α-particle have the same mass as a helium atom, but it is a helium atom, from which the two outer planetary electrons have been removed. The α-particle or helium nucleus in the outer bulb immediately picks up two electrons and becomes an ordinary helium atom as shown in

Fig 13. The small dot in the center is the α-particle or helium nucleus of which Fig. 11 is a magnified picture.

The atomic weight of radium is 226. An atom of radium emits an atom of helium of weight 4 and is transmuted into an atom of the rare gas niton of atomic weight 222. This gas emits helium and is transmuted into RaA, a solid weighing four units less, namely, 218; RaA emits helium and is transmuted into RaB of weight 214. RaB does not emit helium, yet it also is transmuted into a new element called RaC, this time however without change in weight Experiments similar to those performed with α-rays show that when RaB is transmuted into RaC, an electron is emitted with a velocity three quarters that of light. Since the mass of an electron is inappreciable compared to that of the nucleus of a heavy atom, the ejection of this high velocity electron or β-particle does not alter the mass of the parent atom.

We have in radioactive transformations, accordingly, two general processes, one in which an α-particle or helium nucleus is emitted and the other in which a high speed electron or β-particle is projected from the nucleus of the parent atom. Since an α-particle has two units of positive charge, the total net charge on the nucleus of a radioactive atom decreases by two units after the ejection of an α-particle. The atomic number of the transmuted element is accordingly two units less than that of its parent. The new element belongs to the family two columns to the left in the Periodic Table. When a β-particle is emitted, the nucleus loses one unit of negative charge The net positive charge therefore increases by one unit; the atomic number increases by one; and the new element belongs to the family one column to the right of its parent in the periodic table

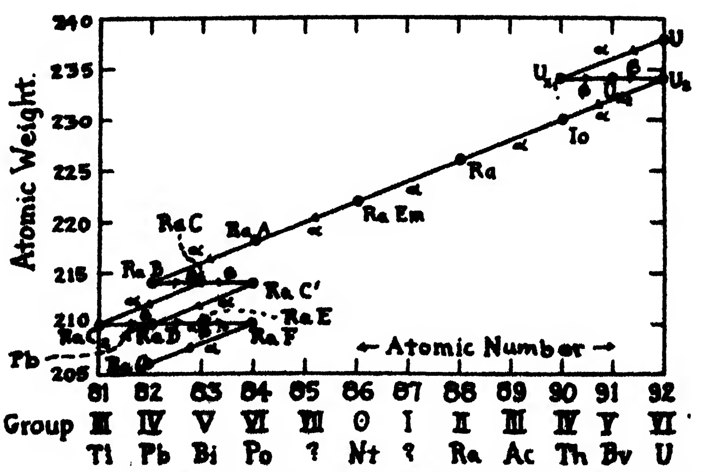


FIG. 14. TRANSMUTATION PRODUCTS OF URANIUM BY RADIOACTIVE DISINTEGRATION

Fig. 14 illustrates this clearly for the entire radioactive group related to radium. Here we have plotted atomic number versus atomic weight. Uranium, a metal of Group VI, atomic number 92, atomic weight 238, emits a helium nucleus and becomes an atom called UX_1, for lack of a better name, a material belonging to Group IV, identical chemically to ordinary thorium and having an atomic number 90 and atomic weight 234 Then follows the emission of two β-particles resulting in U_{II}, an isotope of uranium and exactly similar to uranium except that it weighs four units less Uranium II is transmuted into ionium and helium, ionium is transmuted into radium and helium; radium is transmuted into niton and helium; niton is transmuted into radium A and helium; radium A is transmuted into radium B and helium Up to this point the original atom has emitted 6 α-particles. The atomic weight of radium B is accordingly $4 \times 6 = 24$ units less than that of its first ancestor, uranium, or 214. Radium B then emits a β particle becoming radium C without change in mass Here it has a choice in regard to its mode of disintegration Radium C which is chemically identical to bismuth may emit a helium nucleus and become RaC″ which is chemically identical to thallium, or it may emit a β-particle and become RaC′. Whichever course the atom decides to take, it eventually becomes RaD, an isotope of lead, and then, after the successive emission of two β-particles and one α-particle, the spontaneous disintegration is brought to a close with RaG or lead.

What a wonderful history this lead atom has had! Nature has produced from the uranium atom 15 different atomic species besides eight atoms of helium. Nine of these products may be differentiated by ordinary chemical or spectroscopic analysis; the others are isotopes of some of these fundamental nine, elements of different mass but having the same chemical properties. After being subjected to internal revolution after revolution the torn and distracted uranium atom finds haven as an atom of lead. Only so far as Mother Nature is concerned, however, for it is the intention of the alchemist to continue this process of trial and tribulation in order that lead may be transmuted into gold.

We have described but one family of the radioactive metals. There are two other families, one known as the thorium series and the other as the actinium series. The general mode of disintegration is similar to that of the uranium series. Thorium is transmuted successively into one element after the other, finally becoming lead. Actinium likewise is transmitted into a series of elements and here again the series is closed, as far as Mother Nature is concerned, with the comparatively worthless metal lead. Besides these transformations, potassium and rubidium emit β-rays, probably becoming calcium and strontium respectively. There is further the

possibility that many of the other elements are radioactive but to so slight a degree that the effect is not definitely measurable. Certain experiments have indicated merely the suspicion of radioactivity in ordinary laboratory apparatus, which of course may be due to the actual presence of a recognized radioactive element as an exceedingly minute impurity.

What do these transmutations teach the alchemist? No one is anxious to convert a few milligrams of radium, of which he may be the proud possessor, into a corresponding amount of lead pipe. Nor need one worry seriously lest this occur. The rate at which the spontaneous transmutations take place is sometimes very slow. Thus if one possessed a gram of radium to-day, half of it would still remain as radium after 1,600 years. The production of radium from uranium might appear to be a profitable occupation as uranium is comparatively inexpensive, but here again the time required is too long to interest a single individual. Half of the uranium with which the process is initiated would be converted into uranium X_I, the first stage in the transmutation toward radium, only after the interval of five billion years.

What causes the spontaneous emission of an α-particle from the nucleus of a radioactive atom? We know that the nucleus of the uranium atom, itself a complicated structure, is surrounded by 92 planetary electrons which revolve with tremendous velocity, each in its own elliptical orbit. The orbits are not exactly elliptical however; they are perturbed by the repulsive actions of the other electrons. Each electron therefore travels in a path which may be described as a rosette or an ellipse with a progressive motion of perihelion. At perihelion it can be shown that the electrons in highly elliptical orbits almost penetrate the complicated structure of the nucleus of a heavy atom. It is not difficult to imagine that occasionally the configuration of the nucleus is such that one of these outer electrons at its instant of nearest approach may exert a very large influence upon component parts of the nucleus with which it is nearly in contact. Suppose the revolving electron pulled the α-particle just a small distance from the nuclear electrons which tend to hold it in the nucleus. The electrostatic repulsion of the rest of the nucleus is then sufficient to eject the α-particle from the atom with the tremendous velocity observed experimentally.[5] Now the reason that such a state of affairs happens only

[5] Stated conversely, the computation of this distance on the assumption that the velocity of the ejected α-particle is due wholly to the electrostatic repulsion of the rest of the nucleus gives values comparable with nuclear dimensions, and with perihelion distances for electrons in orbits of high eccentricity. For example, the distance $7 \cdot 10^{-12}$ cm is sufficient to account for the emission of α-particles from uranium with the observed velocity $1.37 \cdot 10^{9}$ cm/sec.

once in an eon, as far as the life of the uranium atom is concerned, may be due to the small probability that the perturbed orbits of the planetary electrons assume just exactly the correct relative positions in order that the forces which the electrons exert may be in resonance with the oscillations in the nucleus itself. If the alchemist had at his command magnetic fields of the magnitudes which must locally exist within the nucleus it is *possible* he could hasten these perturbations and reduce uranium to radium in a reasonable length of time. We are not able to produce such fields but there are other methods available by which the nuclear structure may be influenced, especially with the lighter elements.

We have found that radioactive elements eject helium nuclei and electrons from their nuclear structures. This fact suggests that the nuclei of all atoms are made up of helium nuclei possibly cemented together by the nuclear electrons. The atomic weight of an element should be accordingly an integral multiple of 4, the atomic weight of helium. This is true for a great many elements, but we have elements of atomic weight $4q + 1$, $4q + 2$, $4q + 3$ where q is an integer. The integers 1, 2, and 3 are thought to arise in hydrogen nuclei also present in the nuclear structure. Accordingly, it has been conjectured[6] that the nucleus of any atom is composed of three different types of building block, the hydrogen nuclei or protons, the helium nuclei or α-particles, and electrons. By properly combining these three units we may correctly represent the atomic weight and net nuclear charge of any element, as illustrated in the following table.[7] Here α, p and e refer, respec-

[6] Speculations on this date from Prout 1815, but the theory was first put in quantitative form by Harkins who supports it with evidence from various sources. *Cf.* series of papers in J. Frank. Inst., 1922–3.

[7] The true atomic weight of every atomic species except hydrogen is integral, or at least is usually integral to within 1 part in 1,000. Thus ordinary lithium is a mixture of two kinds of lithium atoms, called isotopes since they are chemically identical, one of atomic weight 7 and other 6. These are present in the ratio 94:6 such that the *mean* atomic weight which the chemist measures is 6.94. While there are only 92 elements chemically distinguishable (five of these are as yet undiscovered) there are possibly 200 atomic species which may be separated and weighed by positive ray analysis.

Slight departures from exactly integral values for the true atomic weights of certain isotopes or elements may be expected from theoretical considerations. For example, higher precision in experimental determinations by the positive ray method *may* show that nitrogen weighs 14.015 instead of 14, and already Aston has observed small but definite deviations from whole numbers in the isotopes of tin.

The accompanying table shows the true atomic weights of the elements up to phosphorus, as *observed* by Aston and by Dempster. The formulae for the nuclear structures are, however, purely empirical; the protons, α-particles and electrons have been arbitrarily grouped to give the observed mass and correct atomic number. For the physical justification of such procedure one should refer to the papers by Harkins, *loc. cit.*, where evidence from many sources, both chemical and physical, is correlated.

tively, to α-particles, protons and electrons, and the subscripts show the number of each required. The expression $\alpha_x\ p_y\ e_z$ is a chemical formula for the nuclear molecule.

STRUCTURE OF THE NUCLEUS

Atomic Number	Elements	Formula	Atomic Weight
2	He	α	4
3	Li	$\alpha p_2 e_1$	6
		$\alpha p_3 e_2$	7[8]
4	Be	$\alpha_2 p e$	9
5	B	$\alpha_2 p_2 e_1$	10
		$\alpha_2 p_3 e_2$	11[8]
6	C	α_3	12
7	N	$\alpha_3 p_2 e$	14
8	O	α_4	16
9	F	$\alpha_4 p_3 e_2$	19
10	Ne	α_5	20[8]
		$\alpha_5 p_2 e_2$	22
11	Na	$\alpha_5 p_3 e_2$	23
12	Mg	α_6	24[8]
		$\alpha_6 p e$	25
		$\alpha_6 p_2 e_2$	26
13	Al	$\alpha_6 p_3 e_2$	27
14	Si	α_7	28[8]
		$\alpha_7 p e$	29
		$\alpha_7 p_2 e_2$	30
15	P	$\alpha_7 p_3 e_2$	31

Accordingly, if we could disintegrate the atoms, the atomic weights of which suggest the presence of hydrogen in the nucleus, we should be able to cause the ejection of hydrogen, in analogy to the ejection of α-particles by radioactive elements. To do this should obviously require considerable energy since atoms are stable in ordinary chemical reactions. Rutherford hoped that the high velocity α-particles, 12,000 miles per second, emitted by RaC would have sufficient energy to penetrate the nuclei of the lighter elements and produce disturbances leading to disintegration. This work proved successful. To Rutherford belongs the distinction of being the first alchemist who definitely transmuted one element into another by artificial means.[9]

It was found that by bombarding boron, nitrogen, fluorine, sodium, aluminium and phosphorus with α-particles of a known energy, hydrogen nuclei were projected from these atoms with

[8] More abundant isotope, *cf.* Aston "Isotopes"—Arnold, 1922.

[9] This may be stated more moderately although such conservatism is unusual. Rutherford was the first to *discover* that nitrogen or aluminium, for example, could be disintegrated by α-particles, a phenomenon which must take place in nature wherever those elements are in contact with a radioactive material. The process is artificial, however, as is the production of a synthetic ruby, because it may be controlled at will in the laboratory. Rutherford's recent work is summarized in four semi-technical lectures which contain references to the original sources. *Proc. Roy. Soc.*, *97*, pp. 374–400, 1920; *Nature*, *110*, pp. 182–5, 1922; *idem*, *112*, pp. 305–12, 1923; *Science*, *58*, pp. 209–21, 1923.

enormous velocities and energies. The identification of the hydrogen nuclei was effected by measurements of their deflection in a magnetic field. Rutherford's experiments are especially conclusive because in every case the energy of the ejected H-nucleus, considered initially at rest, is *greater* than that which it should have derived directly from the impacting α-particle. That is, the α-particle merely disturbs the equilibrium in the nucleus of the disintegrated atom, and it is the repulsive force of the nucleus which contributes materially to the velocity of the ejected hydrogen particle.

This fact eliminates the possibility that the observed hydrogen particles were due to the presence of hydrogen gas as an impurity. Thus it may be shown from simple dynamics, and may be verified directly by experiment, that when α-particles are projected through hydrogen gas, the maximum energy of an ejected hydrogen nucleus, produced by a head-on collision, is 0.64 that of the impacting α-particle. Rutherford found, however, that the hydrogen particles, ejected from the six light elements mentioned, possessed more than 0.64 of the energy of the impacting α-particles, and, except for nitrogen, the energy even exceeded that of the α-particle. Thus the hydrogen particles ejected from aluminium possessed a kinetic energy 37 per cent. greater than that of the α-particles producing them, as illustrated in the following table:

KINETIC ENERGY OF HYDROGEN-NUCLEI

Atomic Number	Element	$\frac{\text{Energy of H particle}}{\text{Energy of } \alpha \text{ particle}}$
5	B	1.02
7	N	.79
9	F	1.10
11	Na	1.02
13	Al	1.37
15	P	1.10
1	H	.64

Hydrogen could not be detected when the α-particles bombarded carbon or oxygen, nor indeed should one expect this, for there is no readily obtainable hydrogen in the nuclei of these atoms, their structural formulae being α_3 and α_4 respectively. Whether or not helium may be ejected from the nuclei of these and other light atoms has not been subjected to experimental test. The liberation of helium (or of any particles) of small range or velocity can not be detected by the experimental methods so far devised.[10]

[10] Let us *hope* that Rutherford's negative results with lithium, chlorine and potassium may be explained in such a manner, since the structural formulae for the nuclei of these atoms are similar to those for the elements showing disintegration. However the whole subject is much more involved than this inadequate summary would indicate. One must refer to Rutherford's original papers.

Rutherford's experiments accordingly definitely prove that the nuclei of light atoms may be disintegrated, resulting in the production of hydrogen. The ejection of a single hydrogen nucleus must decrease the atomic weight of an atom by one unit and likewise must correspondingly decrease its nuclear positive charge and atomic number. The disintegration product, if stable, should be therefore the element[11] immediately preceding in the Periodic Table, as represented by Fig. 15.

Phosphorus becomes silicon of atomic weight 30; aluminium becomes magnesium of atomic weight 26; sodium is transmuted into the gas neon of atomic weight 22; boron becomes beryllium of atomic weight 9. Fluorine should become O^{18}; and nitrogen, C^{13}; but these isotopes are known *not* to exist, so that very likely the ejection of hydrogen from fluorine and nitrogen is followed by other disintegrations in order that stability may obtain. For example, nitrogen might emit both hydrogen and helium and become stable as an atom of beryllium.

With these experimental facts before us we are prepared for the consideration of the real problem of alchemy, the transmutation of the baser elements into gold and other precious metals. But may we pause a moment and reflect upon the economic situation here involved.

If the secret of transmutation of a baser metal into gold is suddenly made public property, and if thereby gold may be pro-

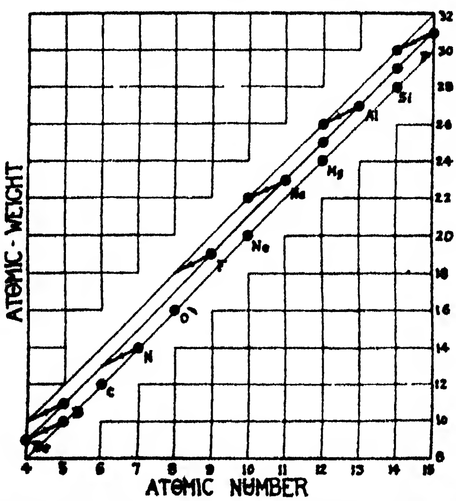


FIG. 15. A reasonable speculation in regard to the disintegration products obtained when hydrogen nuclei are ejected from elements by the Rutherford method.

11 So far there has been no experimental evidence for this conclusion as the amount of the transformation product is too small for analysis. It is, however, reasonable speculation.

duced in unlimited quantities, at the same cost, for example, as iron, a world-wide financial panic will be immediately precipitated, for the currency of every civilized country is based on a nominal or actual gold standard. All governments could immediately pay their total national and international indebtedness, including reparations. Measured in tons of gold, this is not such a huge quantity as one might expect. The holders of government securities would receive the correct amount of gold for their return, but suddenly this would have lost greatly in purchasing power by virtue of the resulting increase in the volume of currency and decrease in the value of the gold. In the same manner the creditor classes, the holders of securities and mortgages, the savings bank depositors, the life insurance policy holders, their fortunes and equities would be practically wiped out of existence. The debtor classes, the borrowers, for a time would luxuriate in the golden flood of wealth and would be able to pay their indebtedness in bullion now of value chiefly for its luster.[12] Undoubtedly the catastrophic situation may be easily saved by a corps of economists—and these are always available—so let us return to our problem.

In Fig. 16, we have plotted the atomic weights of all the known (or reasonably certain) isotopes of elements from atomic number 77 to 83. We shall consider the production of gold, platinum and iridium by the two conventional methods, that of Mother Nature, where an α-particle is emitted, and that of Rutherford which results in the emission of a hydrogen nucleus.

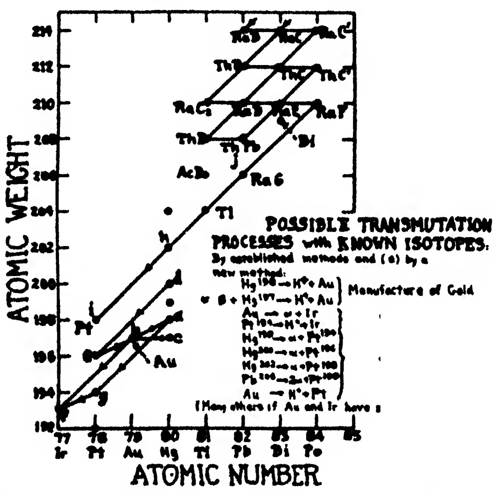


Fig. 16. Methods for producing Gold, Platinum and Iridium from Baser Metals

[12] These depressing predictions were suggested by my colleague, Dr. F. A. Wolff.

If a hydrogen nucleus is ejected from Hg^{198} by an experiment similar to that of Rutherford's, gold should result as shown by the transition *ab*. If gold can be made to emit an α-particle we should obtain the more valuable metal iridium by the transition *bf*. Performing the Rutherford experiment on Pt^{194} should also yield iridium, as shown by the line *gf*. Ejecting an α-particle from each of the three isotopes of mercury, Hg^{198}, Hg^{200}, Hg^{202}, should produce the three isotopes of platinum Pt^{194}, Pt^{196}, Pt^{198}, these transmutations being indicated by the lines *hi, de* and *ag*. From lead of atomic weight 206 we should obtain Pt^{198} after the emission of two α-particles, illustrated by the transition *ji*. The ejection of a hydrogen nucleus from gold by the Rutherford method should result in the production of Pt^{196}, as indicated by the line *be*. Many more transmutations of this type are possible (on paper) if later work shows that gold and iridium possess several isotopes. Still another reasonable means of transmutation is evident if one may drive an electron or β-particle into the nucleus of an atom and compel it to remain there. Thus, in the transition *cb* the nucleus of Hg^{197} attracts to itself a β-particle and becomes a gold atom. One would think that such transmutations should readily occur (experimental evidence to the contrary) since the positive nucleus should exert an attracting force on a negative charge.

These are the conventional or conservative methods for the production of rare metals by alchemical processes. Many other schemes have been proposed and tried but they rest upon a less secure, experimental foundation. For example, some have thought that transmutations may be effected by very high temperature. Now temperatures approaching 50,000° may be obtained by exploding metal wires with sudden application of high voltage and capacity. Wendt[13] has claimed that by so disintegrating a tungsten wire, a quantity of helium 26,000 times as great in volume as the original wire resulted. The tungsten was therefore practically completely dissociated into helium from which it must have been originally synthesized. Bell and Bassett[14] have found that the

[13] *J. Am. Chem. Soc., 44*, pp. 1887–94, 1922. The work is very questionable—in fact it is quite certain that the conclusions were based on unreliable data; others have failed to substantiate his results. However, the fact that huge quantities of energy per atom are involved in disintegration is not an argument, although frequently so stated, that anything like a similar quantity of energy is required to initiate the reaction. Radioactive transformations require no outside agency. The chief argument against disintegration by high temperatures is the fact that even at 50,000° the energy exchanges between atoms are far smaller than may be produced by electronic bombardment, while the latter has proven so far ineffective.

[14] *Science, 56*, p. 512, 1922. One can not find fault so easily with this work. The minute quantity of helium present in the atmosphere is certainly insuffi-

Sperry search-light arc shows seven lines of helium in its spectrum. Whence the origin of this helium if not from the disintegration of carbon or of the atmospheric gases?

Thus if high temperature is required, there are means for its production and the process can be readily commercialized. At present, however, methods involving electrical stimulation appear more definite and promising. The yield of transmuted elements so far secured is unfortunately very small, discouragingly so in fact. From Rutherford's experiments we find that if all the α-particles[15] emitted by a gram of radium and its products in a year were fired into an aluminium target, the liberated hydrogen would amount to 1/1000 cubic millimeter, with a correspondingly small amount of the transmutation product magnesium. Even were the product gold, the method, as so far developed, could not be looked upon as a menace to our present money standard.

Our hope must be therefore in some means for producing α-particles in tremendous quantity and with energy several times that of the fastest α-rays known in radioactive disintegration. There is a possibility that such hopes may be fulfilled. A helium ion falling through a potential difference of 4 million volts will have an energy equal to that of the fastest α-particles. X-ray bulbs have been made to operate at one tenth of this voltage Much may be accomplished when electrons and ions may be driven through electric fields of a dozen times the magnitudes now available.[16] Possibly the general x-radiation from tubes of such high voltage may be employed for the disruption of atomic nuclei and for the transmutation of metals.

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cient to give the observed spectrum. If the helium was not produced by disintegration it must have been present in considerable amount as an impurity, which is obviously surprising.

[15] The number of α-particles emitted in a year attains the stupendous figure $4.5 \cdot 10^{18}$, four and one half billion billion. However, this amounts to less than 0.2 cm^3 of helium gas at atmospheric pressure. The large number of molecules in a small quantity of matter has been vividly illustrated by Aston, J. Frank. Inst., *193*, pp. 581–608, 1922, as follows: "Take a tumblerful of water and label all the molecules in it. Throw it into the sea and wait for a period sufficiently long that all the water on the earth, in seas, lakes, rivers and clouds is perfectly mixed. Then fill the tumbler from any hydrant. It will contain 2,000 of the original molecules, for although the number of tumblers of water on the earth is $5 \cdot 10^{21}$ the number of molecules of water in a single tumbler is 10^{25}." It may be noted that, at 25 cents per trillion, one German mark will still buy 1,150,000,000 atoms of gold.

[16] Experiments at the maximum voltages now attainable are worth while. Several years ago Dr. Trivelli, later of the Eastman Kodak Co., bombarded uranium with high-voltage electrons and obtained some evidence that the radioactivity of the material was increased. The experiments were not continued to the point where definite conclusions could be drawn.

Even if transmutation should be carried out on a large scale of production, its importance to the general welfare of humanity would shrink to insignificance compared to the greater interests which would develop simultaneously. However much may be the good arising in the use of non-corroding girders, in the replacement by platinum of our structural steel buildings and bridges;—however great may be the happiness of the housewife with an array of platinum utensils in the kitchen;—all these are really trivial. No alchemist of the past dared dream of the field opened to the modern physicist, the moment that transmutation is reduced to quantity production. For by whatever means this be effected, the same methods can be employed in the creation of energy by annihilation of mass.

We know from the theory of relativity that energy and mass are associated in the relation $E = c^2m$ where c is the velocity of light. There is more real alchemy in this little equation than in all the thousands of volumes written from the time of Hermes to Lavoisier. Can we grasp the significance of the numerical magnitudes here involved? Let us consider one of the simplest possibilities.

While it is proven that atoms are made up of protons, α-particles and electrons, we are convinced that the ultimate building blocks are simply two in number, the protons and the electrons. The α-particle or helium nucleus is therefore produced by the union of 4 hydrogen nuclei and two cementing electrons, as shown in Fig. 11. The helium atom *may* be synthetically constructed from 4 hydrogen atoms. That helium actually consists of hydrogen should be capable of verification by the Rutherford method of disintegration, so soon as we are able to produce bombarding α-particles with only four times the energy at present available.

Now we know that the atomic weight of helium is 4.00, while the atomic weight of hydrogen is 1.0077. Hence four separate atoms of hydrogen weighs 4.031, or 0.031 units more than when they are compressed together to form an atom of helium. Thus the formation of 1 atom of helium annihilates 0.031 units of mass, and, by the general principle of Einstein, results in the creation of c^2m units of energy. If a gram atom of hydrogen is thus converted into helium, the energy liberated is

$$c^2m = .0077 \times 9 \times 10^{20} = 6.9.10^{18} \text{ ergs.}$$

That is, if the hydrogen in two teaspoonsful of water be converted into helium, 200,000 kilowatt hours of energy is set free, representing $20,000 worth of electrical current or ten thousand dollars to the teaspoonful.

This is a comparatively moderate reaction from the speculative standpoint. Since mass is undoubtedly electrical in nature one may wonder what would happen if the nucleus of the hydrogen

atom should attract into itself an electron. If the nucleus and electron could be united, their charges should completely neutralize one another. It is possible that the original charges should therefore cease to exist and the atom should vanish. The complete annihilation of one gram of hydrogen in this manner would give rise to 130 times the energy available in the formation of helium or $2,600,000 in electrical power. The ancient alchemist desired to create gold. The modern alchemist would destroy it. Complete destruction of one pound of gold represents the production of 10,000,000,000 kilowatt hours of energy.

While these are mere speculations, indeed, so sure are we of the fundamental truth of the alchemical transmutation of hydrogen into helium that the chief scientific interest[17] no longer lies in the consideration of its *possibility*. The real problem from the scientific standpoint is the explanation why all hydrogen has *not* been already transmuted into helium. With such an exothermic reaction why should we have any hydrogen or hydrogen compounds at all? Tolman[18] has given serious thought to this question, which has puzzled the alchemist, and his paper may be commended to those who fear lest even the water disappear from the universe, and we really die of thirst.

In conclusion we have found that some forty different elements or atomic species are transmuted spontaneously in radioactive disintegrations. Many radioactive elements give off helium. The light elements may be transmuted into still lighter elements and hydrogen. We have learned how gold and other precious metals may be made from lead or mercury. When the scientist is able to utilize an electric field of 10 million volts there is small doubt but that every element may be produced by transmutation.

To do this on a large scale of production, to make it a commercial enterprise, is an entirely different proposition. I doubt if many of us will live to see its realization. But when that time comes, this world will be a true haven of rest for all its inhabitants. There will be no poverty, no suffering and no labor; atomic energy will do the work for all mankind. Humanity will be emancipated by the scientist.

Such emancipation is probably desirable, but philosophically it raises a very interesting question. Shall we ever be content to retire from all industrial and intellectual activity and, with atomic energy enslaved, submit to a life of ease and stagnation? I believe not. New problems will be opened requiring even more intense scientific study than those which at present engage our attention.

[17] Speculatively speaking.

[18] *J. Am. Chem. Soc., 44,* pp. 1902–8, 1922.

Possibly this world where we now live will no longer prove a satisfactory abode for the civilization of the future. Problems such as exploration of the stellar space will confront the daring navigator with atomic energy at his command. New worlds may be discovered, so attractive that the inhabitants of this earth all will migrate leaving their former home to the mercy of the processes of evolution. . .

Life here is again evolved through the millions of years; intellectual development again advances to the discovery of atomic energy; the people leave, and so the cycle is repeated, forever and forever.

Now in benediction, may I counsel those who are discouraged and are disappointed in the present status of alchemy, to take comfort in the Proverbs of Solomon, the 16th chapter and the 16th verse, wherein it is written "How much better it is to get wisdom than gold."[19]

[19] Similar advice will be found in the First Epistle of Peter, 1:7.

ADJUSTING AGRICULTURAL PRODUCTION TO CHANGING CONDITIONS

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It is quite apparent to any one who gives the matter serious attention that things are not moving smoothly with the farmer; that he is confronted with certain conditions quite different from those prevailing a generation ago, and that these changed conditions call for some adjustments in crop production and management before he will attain that degree of prosperity and stability to which he has been accustomed. It is perhaps in order to inquire what are some of these changed conditions.

In the first place, there has been a remarkable change in the character of the population of this country. In 1890 there were about 63 millions of people within our borders; in 1920, nearly 106 millions, or an increase of over 67 per cent. in 30 years. In 1890, 43 per cent. of our population lived in cities and incorporated villages and 57 per cent. in strictly rural territory. In 1920, 59 9 per cent. lived in cities and villages and 40.1 per cent. in rural territory, and of the latter only 29.9 per cent. can be classed as belonging definitely to our farming population; in round numbers, less than 32 millions. While *relatively* the farming population has decreased, actually there has, of course, been an increase amounting to some 18 per cent. as compared with 67 per cent. increase in total population.

The farmer finds himself to-day, then, in a country the vast majority of whose inhabitants are engaged in pursuits other than agriculture.

Increase in Agricultural Output

A second change of moment is the greatly increased agricultural output per man. This is brought out quite strikingly when one compares the average annual production of our leading crops in the decade 1889–1898 with similar production in 1909–1918, as follows:

LEADING CROPS OF UNITED STATES

Crop	10-year average production 1889 to 1898 Bus., tons or bales	1909 to 1918 Bus., tons or bales	Percentage increase in 2d period
Corn	1,949,592,500	2,736,424,000	40.3
Oats	760,090,800	1,278,982,400	68 2
Wheat	536,507,400	756,176,900	41.0
Barley	91,850,200	199,815,500	117.5
Rye	30,138,400	48,013,200	59.3
Potatoes	214,989,300	369,903,700	72.0
Hay	52,414,600	74,263,600	41.7
Cotton	8,657,900	12,728,600	47.0

This average increase of over 50 per cent. in the production of the most important staples (omitting rye and barley) is far out of proportion to the increase in rural population. It is proper to note briefly the causes of this increased production. Undoubtedly the most important cause has been the introduction and general use of a truly marvelous line of agricultural implements, thus multiplying the efficiency of the individual man several times for some lines of work. Then the increased use of commercial fertilizers has been an important factor in the older cultivated sections, and finally, the application of science to the art of farming has contributed not a little.

It is quite apparent that we do not need as large a proportion of our population on the farm now as we needed 30 years ago. Indeed, if one were to judge from the present price of many of our staple products a few more farmers might well devote their energies to other lines of industry

RELATIVE PRICES

A third change which is causing great unrest in the agricultural world and is likely to call for some adjustments in production is the price of agricultural products as compared with the price of labor, farm implements, taxes and transportation, particularly the price now as compared with prices before the war. In making these comparisons use is made of what is called the "index number," which is the price relation at a given time to the average price of the commodity for a stated period of time taken as a standard or 100 per cent. In this case the average of the pre-war period 1910–1914 is taken as 100. An index number of 125 accordingly means 25 per cent. above the average price during 1910-1914.

INDEX NUMBERS OF PRICES AND WAGES

1910–1914 = 100

Average for year	Farm products	All commodities	U. S. union wage rate	Farm machinery
1914	105	100	104	102
1915	106	103	105	102
1916	125	130	109	108
1917	194	181	116	138
1918	222	198	136	175
1919	236	210	158	178
1920	222	231	203	175
1921	126	150	209	176
1922	136	152	197	153
1923	144	157	215	165

But the present agricultural situation will be understood better if the large group of farm products be separated into certain specific products. For instance, in December, 1923, corn had an index number of 124, wheat 107, hay 106, potatoes 136, onions 176, butter 161, hogs 95, beef cattle 100, wool 209.

The wide range in prices will at once be noted. With farm labor ranging from 134 in North Dakota to 185 in New York, and averaging for the entire United States 162, with farm machinery at 165, freight rates at 155 and taxes on farm real estate at 204, it is at once seen where the wheat, corn, hay, hog and beef cattle farmer is placed. It should be stated that 85 per cent. of the corn crop is fed to livestock and marketed as such.

Now it must be granted that the farmer got his raise in prices, *first,* as shown by the index numbers table, and might properly expect to take the first drop, but until some items enumerated more nearly approach his standard he will be at a decided disadvantage and have just cause for complaint.

ADJUSTING PRODUCTION

Evidently this situation does call for some adjustments on the part of the farmer. Shall he keep on growing his usual acreage of wheat and corn and maintain his accustomed numbers of hogs and cattle? No general rule of practice can be laid down. Some farmers and localities should most certainly curtail their acreage of these standard crops, while others might well increase their production. It will perhaps turn some light upon the agricultural situation to consider the comparative acreage of our staple crops in a number of representative states. The following table shows what percentage of total acres in harvested crops is in each of several of our leading crops:

STAPLE FARM CROPS IN MANY STATES

State	Total acres in harvested crops	Percentage of this acreage in: Corn	Wheat	Oats	Hay and forage[1]	Potatoes
Iowa	21,609,534	41.7	6.7	25.0	21.1	0.45
Illinois	21,462,852	36.9	19.1	20.1	18.7	0.40
Indiana	13,223,256	33.8	21.2	13.0	25.0	0.47
Ohio	13,934,239	25.6	21.0	10.4	35.4	0.90
Kansas	22,843,587	16.1	49.3	6.2	21.9	0.20
Nebraska	19,432,145	34.5	22.1	10.5	21.9	0.50
So. Dakota	15,313,006	18.0	25.3	12.0	33.1	0.40
No. Dakota	19,760,741	9.7	46.0	10.5	20.5	0.40
Missouri	16,810,354	33.1	27.2	10.2	25.0	0.40
Minnesota	17,149,813	13.9	22.1	20.0	29.4	1.90
Wisconsin	10,265,998	11.1	5.2	22.0	44.1	2.90
New York	8,904,678	3.6	5.1	10.5	61.8	3.50
Michigan	10,000,611	12.7	10.6	15.1	36.4	2.80
Maine	1,650,189	0.4	0.9	7.2	77.8	7.0
Montana	3,924,337	0.5	43.3	4.9	43.0	0.6
						Cotton
Texas	25,534,195	18.6	9.5	7.3	9.4	45.2
Georgia	12,537,645	34.1	1.1	1.5	10.0	37.7
So. Carolina	5,852,376	30.2	1.4	3.4	11.5	45.4
Oklahoma	15,393,796	16.1	30.5	10.2	13.5	17.7
Mississippi	6,603,052	40.3	0.1	0.8	7.3	44.7
Alabama	8,091,496	41.1	0.4	1.0	8.7	32.4

And the following table gives one an idea of the situation as regards our livestock industry:

THE NUMBER OF ANIMALS PER 1,000 ACRES OF HARVESTED CROPS

State	Milk cows	Other cattle	Swine	Sheep
Iowa	56	161	487	43
Illinois	54	72	250	28
Indiana	57	59	293	53
Ohio	78	60	221	152
Kansas	22	111	130	13
So. Dakota	30	101	198	45
No. Dakota	27	41	33	13
Montana[2]	49	310	69	604
Minnesota	98	74	221	25
Wisconsin	216	83	163	33
New York	183	44	63	61
Alabama	64	58	136	11

It is perhaps unnecessary to call attention to these tables in detail. The information carried is quite evident. Some of the storm centers in our present depression are apparently due to too

[1] All silage crops.

[2] Only 3,924,337 acres in harvested crops.

large a proportion of the acreage in cultivated crops in one crop which for the time being is low in price. Low-priced wheat will hit North Dakota and Kansas harder than Wisconsin, Michigan and Ohio. Moreover, it is all but universally true that the states with the largest acreages grow less bushels per acre than states with small acreages, thus greatly increasing their losses.

What is true of crops like corn and wheat is not necessarily true of hay and forage, which are often of the nature of by-products and are generally consumed by local livestock. Instead of sources of trouble, these large acreages may be evidences of a well-balanced agriculture.

What shall be said, then, in the matter of agricultural adjustments? In the first place, it may well be said that radical changes are not called for. The fact that wheat or corn is low in price one year is not proof that it will be low the next year In times of peace the yearly average farm price of corn has changed 70 per cent. in 12 months' time, and the total production has shifted 55 and 60 per cent, with less than one per cent change in the acreage planted to corn It is not an unusual thing for wheat to vary 25 and 30 per cent. in average yearly price, one year following another. Hurried adjustments of acreages to take advantage of high or to avoid low prices are foredoomed to disappointment. The adjuster will usually find himself a year or two behind the crest of high prices.

But greater diversification is assuredly in order in many localities. It would seem to be apparent that states like North Dakota and Kansas, not to mention others, would do well to reduce their acreage of wheat somewhat and increase that of other crops fairly well adapted to the state, and likely keep more livestock. With freight rates as they are now, or as they are likely to be in the near future, more attention must be given to supplying the home market and perhaps less to the foreign market. In the great changes which have taken place in our population previously referred to in this paper, a goodly portion of our foreign market of other days has been set down within our own borders. This naturally calls for large increases in truck crops, fruit and milk. As we properly supply these needs there will be some easement in the foreign market situation.

And "home market" should include not only the United States, one's own state and nearby cities, but the farmer's actual needs in his own home. Not many farmers are supplying as many of their home needs as they might profitably do. The old-time "independent" farmer no longer exists. He can be found only in the pages of fiction. The farmer of to-day depends quite largely upon the department store of the great city and the town grocer and baker.

There should also be as much concentration of products which have to be shipped long distances as possible—more eggs, butter, wool, etc., and less cereals and roughages.

Greater Economy in Production

The agricultural situation will also be greatly helped by more economical production. Anything which will reduce the cost of producing a bushel of wheat or a pound of pork will increase the farmer's net profit as much as an increased price for his product, and will be better than the latter, for it will not tend to decrease the demand for his product as an increased price would have some tendency to do. The latter would also have a tendency to increase the cost of living all around, the farmer included.

Among the things which will make for economy in production is a larger yield per acre. The cost of growing 80 to 100 bushel-to-the-acre corn and 40 bushel wheat is but little more than 30 to 40 bushel corn and 10 to 15 bushel wheat. The farmer who is able to "adjust his production" in the direction of the larger yields mentioned is the one who is going to reap the greater rewards in agriculture.

There are a number of things which will aid the farmer in reaching these desired yields. Among them may be mentioned a reduction in the number of acres farmed During the period of the war many acres were put under the plow and into the production of harvested crops that could be used with profit only in times of very high prices. Their productive power is too low to return a profit at the present time. The best thing that can be done with this acreage is to put it back in pasture where some of it was previously, and some of it in forestry, until the time comes when it can be farmed with profit. This concentration on a reduced acreage will result in higher yields per acre and increased profits.

Unquestionably a larger use of legumes would result in more profitable crop production. At the present time less than one acre in seven of our harvested crops is in legumes, and a large proportion of this so-called legume acreage is only part legume—a timothy and clover mixture. It is doubtful whether we average to have our land in legumes more frequently than one year in eight, in the country as a whole. What would it mean in the way of increased yields per acre if we had legumes one year in four? We have no data showing this fact, but we do have data showing the difference between growing clover one year in five and one year in three. This difference is 7½ bushels of corn per acre and 2¼ bushels of wheat, in favor of clover one year in three. It is fair to presume that legumes one year in four, as compared with one year in eight, would at least mean as much—probably more.

A larger and more general use of commercial fertilizers and of calcium compounds is destined to be an important factor in increasing the yields per acre of all agricultural and horticultural crops. The older cultivated sections have long used these materials with profit, and the corn belt and the northwest are beginning to use them. The proper combination of fertilizing materials for different soils and crops is well worked out, or is fast being done, by the state agricultural experiment stations.

The gains to be secured from the use of the best available varieties of all farm crops are very important in the matter of greater economy in production. Varieties of cereals, for instance, have been developed in many states which will increase the average yields from two to four bushels per acre. Methods of seed inspection and certification of these improved varieties have been put in practice which make the distribution of seed of high quality fairly certain. In some few states these improved varieties are grown on from one fourth to one half or more of the total acreage of the state.

It is important not only that seed of excellent varieties be used, but careful attention must be given to seed treatment and spraying. Potato growing in our best potato sections has made rapid strides recently by the use of disease-free seed and thorough spraying. Our fruit industry has been reborn by the diligent attention given to spraying. New materials for use in spraying and new uses of old materials are continually coming to light. Without doubt developments of great moment will be made in the near future in conquering plant diseases and insect enemies. In some plants, red clover, for instance, much remains to be done in the way of breeding disease-resistant strains.

While great strides have been made during the last 30 years in agricultural output per man, there is no reason to believe that the limit has been reached. New and valuable labor-saving implements are continually coming into use. Men are becoming more proficient in both the science and art of farming. When four million men left the farm to engage in the activities of the World War the complaint that the production of agricultural supplies for our armies and essential industries must necessarily be greatly curtailed was very general. But, strange to say, agricultural production was not reduced. Rather it was expanded to such an extent that the great worry now is how and when can we get back to normal production.

A very little investigation will show that there are almost unbelievable differences in the amount of crop acreage cared for per man in different parts of the country; yes, in different parts of the same state. Some of these differences are perhaps necessary, but many of them are matters of precedent and education. A better

organization of the farm plant; a more intelligent utilization of farm machinery will revolutionize agricultural profits in many sections.

After all is said and done the farmer will very largely have to work out his own salvation. He has done this many times in the past and he can and will do it again. His one unfailing remedy for low prices is to ease up on production—cut out cropping some of his least productive acres and sell some of his labor to nearby industries or public works when the latter offer more for labor than he can get for it on the farm.

It is said that over a million farmers left the farm for other activities during the past two years. This is not as great a calamity, perhaps, as some might think There are evidently more men engaged in farming at the present time than are needed. If they can get better wages elsewhere is there any reason why they should not better themselves, and in bettering themselves, better conditions for those who choose to remain on the farm?

Some of these times the index number for wages will bear a different relation to farm products than it does to-day. When that time comes the drift will set in the other way. While this may seem slow and cruel, there is no evidence to date that there is any better way. As a nation we love to legislate things right, but some things do not readily yield to Congressional edict.

THE PACIFIC SCIENCE CONGRESS

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Preliminary Steps

The Pacific Ocean is a region from which information is meager. It has many interesting problems of its own and not unlikely holds the key to the solution of problems elsewhere. Within the Pacific and around its borders scientific exploration has progressed intermittently for a century; especially during the past quarter century scientists have been actively at work in this region. Government bureaus of the United States and Canada, supplemented by universities and scientific institutions of British Columbia, Washington and California, have recorded much essential information for the Pacific Coast of North America. New Zealand has made important contributions to the natural history of the dominion, together with its outlying islands; Australia is slowly gaining knowledge of its continent and due to the energy and foresight of these two British countries, knowledge of Antarctica has become the possession of the world. For the Dutch East Indies economic studies are far advanced and preliminary reports on geology, botany and zoology have appeared. Since its founding in 1906, the Bureau of Science at Manila has made remarkable progress in gathering data from the 7,083 islands which constitute the Philippines. Japan is as well mapped and described as any Pacific region. In Hawaii science has passed the exploratory stage.

Little is known of the great land masses, Papua and Borneo, and of the islands which lie between them. But the least known part of the Pacific, perhaps of the world, is the lands and waters of Micronesia, Melanesia and Polynesia—a region of islands scattered over about one sixth of the earth's surface. These islands, perhaps 20,000 in number, include some like Fiji, New Caledonia, Tahiti and Rarotonga, for which scientific knowledge requisite for half-hearted commercial exploitation has been recorded, and others for which through the activities of missionaries an outlined picture of the native inhabitants exists, still others for which the knowledge of natural history has received no additions since the days of their discovery. The natural history of many charted islands is unknown, and some have probably never been landed upon. For a large part of the Pacific the standard works of reference are the accounts of Captain Cook, and of such voyages as those of the *Astrolabe*, the

Beagle and the Wilkes Expedition. To gain knowledge of this vast region adequate for even the most urgent needs of science requires the development of a somewhat unusual program.

The Pacific is peculiarly a region where scientific work by the "hit-or-miss," "free lance" method is ineffective. Experience in the study of coral reefs, of former land connections, of race origins and migrations, of the history of Pacific land snails, insects and plants have revealed complexities quite beyond the range of individual workers. To collect single-handed the significant data bearing on even a small division of a small subject would require the years of a Methuselah; and the expense involved in bringing scientific knowledge of the Pacific to the stage reached on the mainland of the United States is beyond the resources of most scientific institutions. Thus it has come about that many of the contributions to Pacific science have increased bibliographies rather than knowledge.

To produce the hoped-for results the essentials seem to be: a group of sympathetic men representing institutions interested in Pacific science, cooperating to save time and thought and funds; a common program of work carefully arranged so that the observations and studies of one group of specialists are directly usable by other groups.

It is with these views in mind that individuals, institutions and governmental agencies have joined in plans for Pacific investigations and, as a means of facilitating the work, have organized the Pacific science congresses Now that these congresses seem likely to attain a permanent place among scientific organizations it seems desirable for historical reasons to record the steps which have led to them and to indicate their scope and purpose.

Like most movements which later result in action, plans for systematic Pacific exploration doubtless have been more or less definitely formulated by many individuals. Few readers of the scientific accounts of Darwin, Dana, Ellis and Langsdorff could lay aside those works without wishing for more extended descriptions, and the many publications of travellers who have found their way to the Pacific point out the opportunity for investigation of unknown areas. To fertile minds within and on the border of the great ocean, the call to exploration must have been insistent and it is not surprising to find schemes for Pacific investigations developing in Hawaii and in California. In 1898 Charles R. Bishop, founder of the Bernice P. Bishop Museum at Honolulu, formulated plans for general Pacific studies in consultation with the officials of the National Museum, and arranged for expeditions to the Marianas Islands in 1900 and to the southern Pacific in 1903.

In 1907 the Pacific Scientific Institution was incorporated under the laws of Hawaii, "to encourage in the broadest sense and most liberal manner investigation, research and discovery in the Pacific Ocean and to make application of knowledge thereof to the improvement of mankind." Although financially well supported, the institution appears to have lacked the leadership necessary to carry its work beyond a preliminary stage.

The idea of promoting joint discussion of Pacific problems began to take form at the Australian meeting of the British Association for the Advancement of Science in 1914.

In 1915 the Pacific region received attention at the Panama-Pacific Historical Congress,[1] which formed part of the educational program of the Panama-Pacific International Expedition. The program of the American Association for the Advancement of Science, which met at San Francisco, also in 1915, included a number of papers on Pacific topics, among them one by Daly[2] which discussed means and methods for further exploration.

In 1916 the attention of the National Academy of Sciences was called to the condition of scientific work in the Pacific through a "Symposium on Pacific Exploration," arranged by Professor W. M. Davis—a discussion which resulted in the appointment of a Committee on Pacific Exploration. Further impetus was given the movement by the Conference on International Relations which formed part of the program arranged for the Semi-Centennial of the University of California in 1918 and by the symposium on "Exploration of the North Pacific," the leading feature of the meeting of the Pacific Division of the American Association for the Advancement of Science in 1919.

At the Honolulu Conference the close of the war projects for Pacific work again came up for discussion and, with a view to uniting all interests in a single organization, the Committee on Pacific Explorations appointed by the National Academy was transferred to the National Research Council, with Professor J. C. Merriam as chairman. With changes in personnel and in name it has become the Committee on Pacific Investigations, attached to the Division of Foreign Relations. The deliberations of this committee, supplemented by informal conferences and extensive correspondence during the years 1916–19, brought out clearly the size and complexity of scientific problems centering in the Pacific and showed the advantages to be gained through coordination of the efforts of individuals, institutions and governments interested in the Pacific.

[1] "The Pacific Ocean in History," edited by H. Morse Stephens and Herbert E. Bolton. The Macmillan Company, 1917.

[2] Daly, R. A., "Problems of the Pacific Islands": *American Journ. Science*, Vol. XLI, pp. 153–186, 1916.

As a means of promoting the desired cooperation, the committee assumed the responsibility of arranging for a conference at which representative scientists from New Zealand, Australia, Java, China, Japan, Canada, continental United States, Hawaii and the Philippines might be present. As a place of meeting the claims of different Pacific cities were considered, but the view prevailed that a conference organized and directed by a committee of the National Research Council should appropriately be held within the United States. The committee therefore accepted the proposal of representative citizens of the Territory of Hawaii that the conference meet in Honolulu in 1920 under the auspices of the Pan-Pacific Union—a Hawaiian organization devoted to developing friendly relations among the different nationalities of the Pacific, especially among those races which constitute the population of Hawaii. From the standpoint of the committee on Pacific investigations the advantages at Honolulu were its strong group of scientific men familiar with Pacific problems, the well-known hospitality and generosity of its leading citizens, and the keen interest of its population in questions which affected the welfare and prosperity of Pacific peoples. A cordial welcome and adequate financial support could be taken for granted.

The scope and purpose of the Honolulu conference is indicated by the following announcement which accompanied invitations:

> The purpose of the conference is to outline scientific problems of the Pacific Ocean region and to suggest methods for their solution; to make a critical inventory of existing knowledge, and to devise plans for future studies. It is anticipated that this conference will formulate for publication a program of research which will serve as a guide for cooperative work for individuals, institutions and governmental agencies.
>
> The program of the conference is in the hands of the Committee on Pacific Exploration of the National Research Council.
>
> The meetings will be arranged to place emphasis on the following topics:
>
> (1) The present status of knowledge of the various branches of anthropology, biology, geography, geology and related sciences in so far as the Pacific Ocean region is concerned.
>
> (2) Research desirable to inaugurate projects to be described in considerable detail with reference to their significance and their bearing on other fields of study. Investigations designed to lay the foundation for a higher utilization of the economic resources of the Pacific may be included.
>
> (3) Methods of cooperation with a view to eliminating unnecessary duplication of money and energy.
>
> (4) The best use of the funds now available and the source of further endowments.

Compared with some other international scientific gatherings, this first general conference on Pacific subjects presented some unusual features. It was a conference of individual scientists rather

than of official representatives of governments and institutions. As a matter of courtesy, complimentary invitations were sent to a selected list of universities, museums, scientific institutions and heads of federal departments, but the particular aim of the committee was to bring together men whose knowledge of the Pacific and interest in its unsolved problems was likely to result in profitable interchange of views.

Financially, the conference was made possible by the guarantee of a group of citizens, appointed by the Governor of Hawaii, and acting as a committee on the Pan-Pacific Union Before the close of the conference considerable territorial funds were made available and these, supplemented by the direct and indirect contributions from local scientific, commercial and social organizations and a federal grant—designed primarily to insure the attendance of scientists in government bureaus—proved abundantly adequate for the payment of travelling allowances, costs of publication and entertainment.

Preliminary organization of the conference was effected by a temporary chairman and a committee on preliminary program, acting jointly for the Committee on Pacific Investigation of the National Research Council and the Pan-Pacific Union When the conference convened, the duties of this chairman and this committee came to an end and throughout its sessions the conference was completely autonomous. It elected its own permanent chairman and other officers and committees, arranged the program from day to day and made provision for future meetings. In order to give time for a personal interchange of views, the program was so arranged that the first week of the conference was devoted to presentation of papers, the second to excursions and informal discussions, and the third to formulation of plans for future cooperative work.

The published reports of the conference[8] show the focusing of attention on comprehensive topics and formulation of programs for investigation. Topics of local and of individual interest were given little place. The subjects chosen for discussion call for contributions from several branches of knowledge. The resolutions likewise call for research in general rather than in specific problems. The topics which received the fullest consideration are: "Race relations of the Pacific;" "Program for anthropological research in Polynesia;" "Origin of Hawaiian fauna and flora;" "Fisheries of the Pacific;" "Biological institutions in the Pacific region;" "Program for work in Pacific volcanology;" "Seismology of the Pacific;" "Mapping of the Pacific;" "Pacific ocean currents in relation to organisms;" "Status of areal geologic mapping in the Pacific

[8] Proceedings of the First Pan-Pacific Scientific Conference: Bernice P. Bishop Museum, Special Publication No. 7, 1921.

region;" "Correlations of post-cretaceous formations in the Pacific region;" "Symposium on means and methods of cooperation;" "Symposium on training of scientists for Pacific work."

The attendance of professional scientists at the conference was 93, distributed as follows: Mainland of the United States, 23; Japan, 4; Australia, 6; New Zealand, 3; the Philippines, 4; Canada, England, China, 1 each; Hawaiian delegates from the staffs of the University of Hawaii, the Volcano Research Association, the Sugar Planters Experiment Station, the Bishop Museum and the federal and territorial scientific bureaus, 39

After provision for publication and for interchange of information had been made, with votes of thanks to the organizations and individuals whose generosity and courtesy had surrounded the delegates with facilities for effective work under pleasing conditions, the First Pan-Pacific Conference adjourned with a strong feeling that the conference marked a definite forward step in scientific investigation. Fundamental problems had been outlined and important contributions to facts and principles and methods had been made; close personal relations had been established and the necessity of submerging national "interests" "spheres of influence" and "rights" in a cooperative effort to gain fuller knowledge of the Pacific had been recognized.

It was, therefore, with regret that the conference found itself faced with the necessity of adjourning *sine die:* it was in no position to effect a continuing organization or even to arrange for a second meeting. For, although the committee of the National Research Council stood ready to organize another conference on American territory, it was recognized that effective international cooperation involved invitations to future conferences emanating from countries other than the United States. The hope was expressed that New Zealand or Australia might extend an invitation to be followed in turn by Japan and Canada. These hopes have been realized in the Pacific Science Congress which met in Australia, August 13 to September 3, 1923, by an invitation to meet in Japan in 1925, and by the prospect that Canada may arrange for a session in 1929.

THE AUSTRALIAN CONGRESS

The Australian Pacific Science Congress (1923) presented features of special interest in its organization, conduct and program. As compared with the Honolulu conference it was broader in scope, more generously financed and exerted a wider appeal. Unlike the Honolulu conference, in which the government took no direct part, the Australian Congress was an official governmental affair. It was financed by the commonwealth government and by the state

governments of Victoria and New South Wales; invitations were issued to other countries through the departments of state and arrangements for the congress were intrusted by the government to the National Research Council of Australia, which in turn placed the responsibility for the scientific program in the hands of a Science Congress Committee. For making local arrangements for meetings of the congress in Melbourne and in Sydney, state committees were also formed. The official control extended to the selection of general officers, chairmen and secretaries of sections, and committees charged with the conduct of the meetings. The delegates were guests invited to a previously prepared intellectual feast in the arrangements for which they had no responsibility. Outside of the sessions of the congress, entertainment was provided on a remarkably generous scale. Each delegate was the personal guest of some interested citizen, and federal, state and city officials joined in offering hospitality. Many local excursions were arranged to suit the wishes of delegates and, without cost to them, the way was opened for visits to Tasmania, to the Central desert, to the Great Barrier Reef and to more distant localities involving a transcontinental journey.

Some of the papers presented at the Melbourne and the Sydney sessions were technical discussions of map-making, earthquakes, geological formations, classification of plants and of animals and similar topics of chiefly professional or local concern; but the distinguishing character of the congress, especially of the Sydney session, was the serious but optimistic discussion of matters of vital importance to dwellers in the Pacific. The program made provision for general and for sectional meetings. The general meetings were arranged with a view to bringing the knowledge and experience of all the scientists to bear on outstanding general problems, especially those which call for international cooperation; the eleven sectional meetings, attended chiefly by specialists, permitted discussion of details. Such topics as "general structure of the Pacific and its influence on plant and animal life," "coordination of scientific work in the Pacific region," and "the relation of the climate of the Pacific to economic and social life" received much attention. The control of insect and plant pests was a section topic for three days, and the conditions controlling the expansion of Pacific agriculture and fishing and stock-raising were treated at length at the congress, and gave rise to discussions in the daily press. The greatest popular interest was shown in the conferences dealing with the dwindling native races in Polynesia, Micronesia and Malanesia, and in the discussions and public lectures on the eradication of tropical diseases. The interest developed more and more as the evidence came in from

Tahiti, New Zealand, Fiji, the Philippines and Java that sanitation, medical skill and sympathetic administration might reproduce throughout the Pacific islands the conditions in American Samoa, where the native population has increased 42 per cent. during the past 20 years. In its highest sense, the Australian meeting was a conservation congress in which the fundamental problems underlying the development of resources were discussed by an unusual group of competent scientists

In addition to the large number of Australian scientists and laymen the congress was attended by 82 overseas delegates, distributed as follows: Great Britain, 12; the Netherlands, 2; New Zealand, 13; Japan, 11; the Philippines, 5; Dutch East Indies, 4; British Malaya, 2; Hawaii, 6; Canada, 3; United States Mainland, 17 (including 7 appointed by the secretary of state); and one each from France, Chile, Hongkong, Fiji, Tahiti, New Guinea and Papua.

As a result of the deliberations of the Australian Congress, projects were outlined and formulated in a series of resolutions.[4] They may be classed as follows:

(1) *Projects preferably to be carried out by the governments primarily concerned:* These include: Sail surveys of Pacific islands; completion of the international topographic map; establishment of a geophysical and astronomical observatory in the Caroline Islands; botanical surveys of Macquarie Island, the Aleutian Islands and Krakatoa Island; geographical survey of Fiji; maintenance of the observatory in British Samoa; establishment of a seismological and volcanological station at Rotorua; provision for transmission of daily time signals from Papeete, Funabashi, Cavite, Bandung, Perth, Adelaide, Melbourne, Sydney and Wellington; establishment of scientific time signal at Pearl Harbor.

(2) *Projects chiefly concerning Australia:* Establishment of a Bureau of Entomology, a federal geologic survey and topographic survey, a solar physics observatory and a forest products laboratory; a study of the Great Barrier Reef; provision for the teaching of anthropology in Australian universities; provision for the publication of the work of the Toolangi Magnetic Observatory; a veterinary survey of Papua.

(3) *International committees:* The following committees were appointed by resolution with instructions to report at the Japanese session of the Pacific Science Congress: on selection of critical areas of crustal unrest; on methods of investigation of salinity, temperature and currents of Pacific waters; on the status of genetic research now in progress; on arrangements for daily records of

[4] Gregory, Herbert E., "Resolutions adopted at the Australian Meeting of the Pacific Science Congress," *Science*, Vol. LVIII, pp. 502–507, 1923.

static at wireless stations and on permanent organization and draft of a constitution.

(4) *Uniform records:* Many of the field notes and specimen labels relating to the published and unpublished investigations of past and present students of the Pacific have been made without reference to the needs of fellow-workers and because of this satisfactory correlation is impossible. To avoid the continuance of this condition, the general adoption of uniform field records and labels was recommended—specifically, for botany, the forms in use in Java, the Philippines and Hawaii; for anthropology, the field record devised for the Bayard Dominick Expedition. It is believed that with suitable recording blanks the observations of amateurs and laymen may be directly utilized.

(5) *University instruction:* Resolutions call attention to the dearth of treatises and the absence of university courses designed to train students for Pacific work, particularly in economic entomology, botany and anthropology.

(6) *Conservation:* Reservation of land on which the tallest eucalypts stand and of Australian timber-bearing areas; setting aside of areas in the Pacific for the preserval of unique fauna and flora; reservations for restoring depleted herds of fur seals, sea otters, whales, elephant seals and dugongs; survey of the organic productions of the Pacific; a study of the insect pests of sugar cane and of other tropical agricultural plants. The Congress resolved that "the scientific problem of the Pacific which stands first in order of urgency is the preservation of the health and life of the native

General Comment

The two Pacific science congresses have been characterized by seriousness both among the delegates and by the communities in which they were held. As with other scientific gatherings, personal relations were strengthened and enlarged, the results of interesting discoveries and observations were presented, and a few young men were given the opportunity to make their initial bow to the scientific world. But these features were incidental to the main purpose of the gatherings, which was to bring the facts and methods of the different branches of science to bear directly on one problem. The desire to advance the interests of anthropology, botany, geology, geography and zoology was submerged in the earnest purpose to make these subjects contribute to the welfare of the people within and around the Pacific. This purpose was the more readily attained because most of the delegates to both congresses represented governments and institutions which had not only recognized responsibili-

ties, but also authority and financial means. The resolutions adopted are not generalized statements of obvious possibilities in the advancement of science, they relate to urgent, well-defined pieces of work within the scope and means of the institutions and government bureaus concerned. Most of the investigations called for by the Honolulu Conference have been completed or are in progress and work has already begun on several projects outlined by the Australian Congress. All of them involve specialists in different branches of science and financial support from more than one source.

The serious meaning of the Pacific congresses is recognized by the communities in which the meetings are held. Experience has brought the conviction that science holds the key to the development and utilization of the natural resources of the Pacific; that Pacific agriculture, stock-raising and fisheries can be made profitable and social life agreeable only in so far as the habits of insect and plant pests, animal breeding, distribution of fish and conditions surrounding physical and mental health of the native and introduced human population are understood. Doubtless for this reason, leading citizens have attended both congresses as listeners (more than one thousand persons were present at some of the meetings in Sydney) and the discussions of the congresses have been treated by the newspapers as "front page stuff" to a degree unknown on the United States mainland. The demand for the Proceedings of the Honolulu Conference long ago exhausted the supply. Doubtless, also, for this reason financial support has been abundantly forthcoming. For the Honolulu Conference, in addition to time freely given by many individuals, the financial contributions of Hawaii from the Territory, individuals and scientific commercial and social organizations amounted to about $30,000. For the Australian Congress the amount contributed directly or indirectly reached a total estimated at $75,000.

The subject-matter of the congresses so far held lies chiefly in the field of ethnology and natural history with their obvious ramifications into mathematics, psychology and the social sciences and within this field no attempt has been made to distinguish between so-called "pure science" and so-called "applied science." It is probable, however, that physics and chemistry will be represented at future congresses, and it appears not unlikely that in association with these congresses or through a separate organization provision may be made for cooperative investigations in Pacific history and economics.

THE PHYSICAL BASIS OF DISEASE

II. LOCAL TISSUE DEATH

By THE RESEARCH WORKER

STANFORD UNIVERSITY

"As our second group of diseases," continued the research worker, as the train pulled out of North Platte, "I have selected diseases caused by rupture, loss, death or destruction of important tissues. You are familiar with diseases of this type in external parts of the body. The type is also common in internal organs.

"Rupture, loss or death of external parts of the body may be caused by numerous agents. Mechanical violence, for example, may produce the various types of incised or contused wounds with which you are familiar. Death of tissues may result from exposure to heat, cold, X-ray or chemical agents. A frequent cause of death of external tissues is the action of disease-producing microorganisms These use the tissues as food, or kill them with their chemical products."

"The germ theory is nonsense," said the man from Boston.

"Our knowledge of the destruction of tissues by microorganisms is no longer in the theoretical stage. It is part of established biological science. Microorganisms are readily visible in killed tissues. They may be isolated from these tissues. Tissue death may be produced by them in laboratory animals. A certain microorganism that was isolated from war wounds, for example, if injected into the leg of a guinea-pig will kill and digest this leg. Twenty-four hours later, the leg is reduced to a bag of dead skin filled with a soft putty-like mass containing naked bones and tendon shreds.

"One of the less common causes of death of external parts of the body is interference with local circulation. The blood vessels, as you know, are muscular tubes, opening and closing under the influence of the nervous system. By electrical or chemical stimulation, arteries may be thrown into such strong contraction that circulation practically ceases. In certain neurotic individuals prolonged contractions of blood vessels occur, sufficient to cause death of fingers or toes. Local circulation may also be interfered with by rupture of the main artery supplying a part, or by the plugging of this artery with solid masses brought from other parts of the body. Circulation may be also stopped by the local clotting of the circulating blood."

"I thought clotting was due to exposure to air," said the manufacturer.

"There is a constant tendency of the circulating blood to coagulate. Coagulation is normally prevented by several factors Among these are the rate of bloodflow and the physical condition of the blood vessel walls. Clotting within blood vessels can be produced in experimental animals by prolonged local stagnation of the circulating blood, or by injuring the blood vessel walls."

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"Death of external parts of the body is followed by local reparative processes. The first of these processes is the formation of a zone of demarcation between the living and dead tissues. This demarcation zone is characterized by the multiplication of certain local cells and by local deposits of white blood corpuscles. The new-formed cells and locally deposited corpuscles penetrate a short distance into the dead area. These cells and corpuscles are capable of digesting dead tissues. The dead mass is liquefied at the point of junction with the living parts. This ultimately leads to its mechanical separation from the living body.

"Certain lower animals have the power of regenerating lost parts—a new leg, new claw or even a new brain growing from the stump of living tissue In human beings, however, regeneration of external parts is practically limited to the skin and underlying supporting tissues. The exposed living tissues are gradually covered by ingrowing skin On aging, the new skin usually contracts, forming white, semi-bloodless scar-tissue. This contraction is often sufficient to cause puckering or deformity of adjacent structures.

"Aside from its local effects, loss or death of surface tissues may cause serious constitutional symptoms. The exposed subcutaneous tissues, for example, furnish an easy portal of entry for disease-producing microorganisms. These may eventually reach important internal organs. Blood-clots set free from superficial blood vessels may be carried to important internal parts. Chemical products absorbed from the dead tissues may seriously injure internal tissues. Enough toxic substance is absorbed from superficial burns, for example, to cause marked degenerations in the heart and kidneys, and even to cause death within a few hours. The action of these toxic substances has been extensively studied on animals, particularly during the late war."

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"Processes similar to those in external parts take place in internal structures. A good example of death of internal parts is the

rupture or erosion of heart valves in certain types of heart disease. The aortic valve is the simplest example. This valve, as you know, is so shaped as to fold back against the aorta during the contraction of the heart, so as to offer little or no resistance to the forward passage of blood. On the relaxation of the heart, the aortic valve closes, preventing a backward flow of the blood to the heart. Disease-producing bacteria are often deposited on the aortic valve from the circulating blood. By their growth and chemical products they may so weaken the aortic valve that the valve ruptures. The valve may even be completely destroyed by them.

"The effects of rupture of the aortic valve have been studied on experimental animals. A small hook is passed down a large neck artery of a dog till it reaches the heart. With this hook the aortic valve is readily torn."

"What a hideous thing to do to a dog!" exclaimed the man from Boston.

"Such operations, of course, are always done under combined morphine-ether anesthesia or its equivalent. Aseptic precautions are always taken, often superior to the precautions used in human surgery. In twenty years' experience in research laboratories, I have never known of an exception to this rule. Operations on animals are always undertaken for a serious purpose, either to acquire facts necessary for an understanding of human disease, to prepare material to be used in human diagnosis and treatment, or to train medical students.

"The aortic valve thus torn is no longer capable of preventing the backward flow of blood from the aorta. On the relaxation of the heart, a portion of the aortic blood regurgitates, reducing the amount of blood passed forward to the general circulation. The dog heart, however, has remarkable adaptive powers. Within three or four heartbeats, the amount of blood thrown out into the aorta at each heart beat is increased two or three fold. Deducting the amount lost by backward leakage, the volume of blood sent forward to the general circulation is thus restored to normal. A dog with a torn aortic valve experiences no inconvenience in his ordinary activities. I recall one dog taken home by a group of medical students, that developed into the champion fighter of his neighborhood."

"It's immoral to use dogs this way," said the man from Boston.

"This dog was used to train medical students in the pathology of circulation. They obtained first hand knowledge from this animal, which they could have obtained in no other way. This knowledge they applied later to the diagnosis and treatment of human disease. The knowledge so gained has undoubtedly been

the means of saving human life. I feel it would have been immoral for us not to have used this dog for the purpose. Incidentally, the dog was a half-starved stray, was brought to the laboratory with the hair scalded off from a large area of its back, and at autopsy over twenty bird shot were removed from its hind quarters.

"A ruptured or eroded aortic valve has serious consequences in spite of the fact that a practically normal circulation is readily maintained. The normal heart rarely uses more than 10 per cent. of its maximum power. A heart with a ruptured aortic valve is forced to do from two to three times its usual work, in order to maintain normal circulation Such a heart is constantly working at a capacity equal to that of a normal heart during violent exercise. Its reserve capacity or factor of safety is reduced. It may be incapable of meeting emergency needs of the body. The dog in question developed symptoms of circulatory insufficiency if taken for a half-mile run.

"Rupture or erosion of the aortic valve is usually followed by local reparative processes The eroded surfaces are gradually covered or converted into scar tissue. On aging, this scar tissue contracts, narrowing the aortic opening. The aortic opening is thus often reduced to half or even a quarter of the normal size. This narrowing introduces a second mechanical factor in aortic valve disease—an increased resistance to the forward passage of the blood to the aorta. The heart automatically compensates for this increased resistance by increasing the strength of its contractions. The general circulation may still be maintained to its normal level. The reserve capacity or factor of safety of the heart, however, is greatly reduced."

"A second example of destruction of tissue in internal organs is death of a portion of the heart wall or heart muscle. Microscopically the heart wall is seen to be composed of muscle fibers, held in place by supporting tissues. The nutrition of the heart wall is derived from small branches of the coronary arteries. Each coronary artery supplies a definite portion of the heart wall. A coronary artery is occasionally occluded. The portion of the heart muscle supplied by this artery is deprived of oxygen and nutrition. Death of the individual usually occurs almost instantaneously. One or more of the branches of a coronary artery, however, may be occluded without causing death of the individual. The local muscle fibers die, are liquefied and absorbed, leaving a portion of the heart wall represented only by inert supporting tissues, or scar tissues.

"The effects of death of a portion of the heart wall are less than one would expect. The individual may have no very noticeable

cardiac symptoms. The reserve strength of the uninjured portions of the heart wall is sufficient to maintain normal circulation. Such a heart, however, may be unable to meet emergency demands.

"A third example of death of internal tissues is death of a portion of the walls of the arteries. The nutrition and oxygen supply of all but the innermost layer of the artery wall is derived from minute blood vessels entering the wall from the exterior. These minute blood vessels are frequently occluded. Portions of the artery wall die and are liquefied. Rupture of the artery may take place, or the artery may bulge to form an aneurymal sac "

"Is that what is meant by 'hardening of the arteries'?" asked the manufacturer.

"Hardening of the arteries is a non-technical expression applied to any process increasing the stiffness of the artery wall. The term is occasionally used to designate deposits of lime in artery walls. Small quantities of lime are present in the circulating blood and in all body fluids. Dead tissue in any part of the body undergoes chemical changes that tend to cause a local precipitation or deposit of this lime. Sufficient lime may be deposited in dead portions of an artery wall, for example, to change these portions to almost stone-like hardness."

"Loss, death or destruction of tissue frequently occurs in the respiratory system. One of the best examples is cavity formation in tuberculosis. Tubercle bacilli usually gain admission to the body through an external wound or through the gastro-intestinal tract. They are usually brought to the lungs by the circulating blood."

"I thought pulmonary tuberculosis came from inhaling dust," said the lawyer.

"The popular emphasis placed on dust as the main or sole cause of pulmonary tuberculosis is not in accord with our present experimental evidence. It is almost impossible to infect normal laboratory animals with tuberculosis by causing them to inhale infected dust. Tubercle bacilli, however, injected into any part of the body, often gain admission to the blood stream and are deposited in the lungs. Large areas of the lungs may be killed by these microorganisms. The dead areas are gradually liquefied and partly absorbed. The unabsorbed residue is usually changed to stone-like hardness by lime deposits. If a fairly large bronchus is included in the dead area, however, this bronchus may be eroded, and the partially liquefied dead portions of the lungs discharge to the exterior. This leaves an open space or cavity in the lungs which is usually surrounded by a zone of scar tissue.

"The destruction of a portion of the lungs is not in itself a very serious matter. There is a large reserve capacity, or factor of safety, in the lungs. Over half of the lungs of a dog, for example, may be removed without interfering with ordinary respiration. The reduction in lung volume, however, is but one of the factors causing symptoms in pulmonary tuberculosis There is always absorption of toxic substances from the infected area."

"Loss, death or destruction of tissue is equally common in the digestive tract. A good example is death of a portion of the intestine following mechanical interference with local circulation. The blood vessels, as you know, reach the intestines by way of the mesentery or intestinal suspensory ligament. The effects of ligating these blood vessels have been studied on dogs. Research workers have found, much to their surprise, that ligation of the main mesenteric artery supplying an intestinal loop is usually without serious effects on that loop. There is a very large factor of safety in intestinal circulation, numerous unions between blood vessels of adjacent portions of the intestine. It is only when the mesenteric artery supplying a very long loop is ligated, and when all mesenteric collaterals are tied that the loop dies.

"Mechanical interference with intestinal circulation sufficient to cause death of a portion of the intestine may be produced in several ways. Mechanically twisting an intestinal loop upon itself, for example, will cause death of the part. Such a twisting of an intestinal loop occasionally occurs after mechanical violence. The twisted loop often possesses a congenitally elongated mesentery. Death of a portion of the intestine is also occasionally brought about by the portion being swallowed by an adjacent intestine. The swallowed portion is passed downward with the intestinal contents."

"Such cases are always fatal," said the manufacturer.

"They are usually fatal if not promptly relieved by surgical methods. Spontaneous recovery, however, occasionally occurs. The swallowed portion of the intestine, for example, is occasionally pushed out before tissue death occurs. Occasionally the swallowed portion sloughs off and is passed out of the body with the intestinal contents, the two segments of the intestine growing together at the point of swallowing."

"Probably the most interesting examples of loss, death or destruction of internal tissues are found in the nervous system.

The simplest of these is pressure paralysis. It occasionally happened in pre-Volstead days that a man went to sleep with his arm over the back of a park bench, and woke up with his fore-arm paralyzed. The paralysis usually passed off in a few days, but occasionally lasted for weeks or months. Recovery, however, eventually took place. Microscopic examinations of such cases show an injury to the main nerve trunks at the point of pressure, with death and disintegration of the nerve fibers beyond that point. The disintegrated fibers are gradually absorbed. New fibers gradually grow downward in the nerve trunks from the nerve stump. These new fibers make connections with the muscles. Voluntary movements are resumed.

"A slightly more complex example of tissue death in the nervous system is seen in infantile paralysis. The causative agent of infantile paralysis finds the gray matter of the spinal cord extremely susceptible to its influence, so that areas of this gray matter are killed. This gray matter, as you know, contains nerve cells whose prolongations or fibers pass downward along the nerve trunks to the muscles. The muscles or portions of muscles receiving fibers from the dead area are permanently paralyzed."

"We have a case near us," said the manufacturer. "The paralysis wasn't permanent. At least, it is very much improved."

"Outside of the portions of the gray matter actually killed by the infectious agent, minor injuries are produced in adjacent portions, from which recovery gradually takes place. These minor injuries usually give temporary paralysis. The part of the paralysis due to actual death of gray matter is permanent.

"Another example of death of portions of the spinal cord is seen in late stages of syphilis. The killed area in such cases usually does not include the gray matter, but is confined to certain portions of the white matter. The portions of the white matter thus destroyed contain fibers carrying sensations from muscles, joints and tendons. The individual has little or no knowledge of the degree of relaxation or contraction of his muscles, or of the position of his extremities. Such individuals usually guide their movements by the sense of sight. They are often unable to stand or walk after dark. The dead portions of the spinal cord do not regenerate."

"I have an acquaintance with locomotor ataxia," said the manufacturer. "He could hardly walk two years ago. He gets around fairly comfortably now."

"The destruction of sensation is rarely complete. Much can be accomplished by systematic training or education of the residual sensations. Your acquaintance has undoubtedly had such systematic training."

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"Very complex symptoms may be produced by loss, death or destruction of portions of the brain or of adjacent nerve trunks. One of the commonest causes of death of portions of the brain is rupture or occlusion of brain arteries. The factors of safety in the brain circulation are very small compared with those of the intestine, so that occlusion of almost any brain artery leads to death of portions of the brain.

"The effects of tissue death in the brain and adjacent nerves vary with the location and extent of the portions involved. If certain relatively small brain areas are destroyed, death of the individual results almost immediately. Large areas, however, may be destroyed without causing death of the individual. There are often marked motor or sensory disturbance The various sensations, as you know, pass along definite paths, or relay of paths, in the brain. Destruction of any part of this path interferes with these sensations, causing various types of partial or complete blindness, deafness, loss of olfactory or gustatory sense, or of the sense of equilibrium. Muscular movements are initiated in certain brain areas, and pass along definite paths or relay of paths. Destruction of any part of this path gives partial or complete paralysis, or interference with muscular coordination and control. Partial or complete loss of certain memories may follow destruction of certain brain areas. The symptoms following destructive lesions in about a third of the brain are fairly definitely known. Destruction of other portions of the brain gives less definite symptoms. They show themselves mainly in reduced mental powers and alterations in character."

"Alterations in character!" said the man from Boston. "The soul can't be changed by a little injury to the brain."

"That depends on your conception of the relation between the soul and the brain There are biologists so bold as to believe it will eventually be shown that all phenomena we include under the term mind or soul are merely manifestations of brain activity. They believe no factor is concerned in mental life except the ordinary physical and chemical factors in the nerve cells. According to their belief, destruction of parts of the brain destroys part of the mechanism necessary for the formation of the mind or soul. Most people, however, look upon the mind or soul as a separate entity, living in or working through the nervous system. According to their belief, destruction of parts of the brain destroys part of the mechanism necessary for the outward manifestations of the mind or soul. Formal biology has no quarrel with persons who hold either of these views. The subject is beyond the reach of formal science.

"That destruction of certain brain areas will alter conduct or character, however, is well established. Many brain areas serve as inhibiting mechanisms, holding in check automatic, reflex or instinctive tendencies originating in other parts of the body. Destruction of an inhibiting area may readily lead to unsocial conduct. Many a man has been hung or electrocuted as a result of a destructive lesion in an inhibiting area of his brain."

"First call for dinner!" announced a voice from the corridor.

"I have two children somewhere on the train," concluded the research worker. "I'd better round them up before the dining car is filled."

A HUNDRED YEARS OF ELECTRICAL ENGINEERING[1]

By Professor G. W. O. HOWE, D.Sc.

THIS section of the British Association, over which I have the honor to preside, is concerned with the whole field of engineering, civil, mechanical and electrical. Within recent years the great developments which have taken place in each of these branches have necessarily led to a high degree of specialization, with the result that a man may have an expert knowledge of one branch but a very slight knowledge of the other branches; in fact, the scope of a single branch is now so extensive and the amount of research work being done so great that it is impossible to keep abreast of the developments in one's own special subject unless one concentrates upon it to a degree that leaves little leisure for cultivating other branches of engineering. These considerations influenced my choice of a subject for this presidential address. As an electrical engineer, I felt that I should be expected to deal with some branch of electrical engineering—indeed, I should not feel competent to discuss any other branch—but, in view of the facts to which I have referred, I decided not to deal in detail with any single section of the subject, but to review the past development and present position of the subject as a whole.

The time for such a review is opportune. William Thomson, afterwards Lord Kelvin, the only man who has ever been elected three times (in 1874, 1889, 1907) president of the Institution of Electrical Engineers, was born on June 26, 1824. He was closely associated with the British Association and for sixty years took an important part in the meetings. He was president of the Association at the Edinburgh Meeting in 1871, and was several times president of section A. I wonder what the members of the organizing committee of section G would think if the president, in addition to reading his address, offered to contribute twelve papers to the proceedings of the section: this is what Kelvin did as president of section A at the Glasgow meeting in 1876. I can find no record of his taking any part in the proceedings of section G, although his brother, James Thomson, was president of the section at the Belfast meeting in 1874.

If any one event can be regarded as the birth of electrical engineering, it is surely the discovery by Faraday in 1821 of the prin-

[1] Address of the president of the Section of Engineering of the British Association for the Advancement of Science, Toronto, August, 1924.

ciple of the electro-motor; that is, that a conductor carrying a current in a magnetic field experiences a force tending to move it. It is noteworthy that ten years elapsed before Faraday discovered, in 1831, magneto-electric induction; that is, the principle of the dynamo. Four years later, Sturgeon added the commutator or "uniodirective discharger," as he called it, and in 1845 Cooke and Wheatstone used electromagnets, which Sturgeon had discovered in 1825, instead of permanent magnets. It was during the years 1865–1873 that the shunt and series self-excited dynamo, using a ring or drum armature and a commutator of many segments, finally evolved.

The early workers in the field do not appear to have realized the intimate connection between the dynamo and the motor, for, although the principle was discovered by Lenz in 1838, it only appears to have become generally known that the same machine could be used for either purpose about 1850. The principle underlying the whole modern development of electrical engineering—viz., the generation of electrical power by a dynamo, its transmission to a distant point and its transformation to mechanical power by an electric motor—appears to have evolved about 1873. An interesting light is thrown on the subject by a paper read before the Institution of Civil Engineers in 1857 by Mr. Hunt on "Electromagnetism as a Motive Power." In this paper the possibility of driving electromagnetic engines—that is, electric motors—by currents derived from voltaic batteries was discussed in the light of Jacobi's discovery of the back-electromotive force in these machines. He concluded that power so generated would be sixty times as dear as team-power, and that it would be far more economical to burn the zinc under a boiler than to consume it in a battery for generating electromagnetic power. The leading scientists and engineers who took part in the debate all agreed that electromotive power was unpractical and impossible commercially. William Thomson sent a contribution in writing which concluded with the following sentence: "Until some mode is found of producing electricity as many times cheaper than that of an ordinary galvanic battery as coal is cheaper than zinc, electromagnetic engines can not supersede the steam engine." As S. P. Thompson says, "Faraday's great discovery of 1831 notwithstanding, the real significance of the dynamo had not yet (in 1857) dawned upon the keenest minds of the time." Six years before this, Thomson had suggested the experiment of driving a "galvanic engine" from a thermal battery, and had stated the problem in terms which show that he already had a correct grasp of the theory of the efficiency of the electric motor.

It was at the Manchester meeting of the British Association in 1861 that Charles Bright and Latimer Clark read a paper proposing

names for the principal electrical units; the names were "galvat" for current, "ohma" for electromotive force, "farad" for quantity, and "volt" for resistance. This paper led to the appointment of the celebrated Electrical Standards Committee of the British Association, which, after six years of strenuous work, produced the system now adopted internationally.

One of the earliest applications of the dynamo was for lighting arc lamps in lighthouses; in 1863 Thomson, writing to a friend on the relative merits of the Holmes direct-current and the Nollet alternating-current lighthouse machines, says, "Thus Nollet escapes the commutator, *a great evil,* and gets a flame which does not burn one of the points faster than the other. The reverse of each proposition applies to Holmes. *The commutator is a frightful thing* . . . the thing to be done at the requisite speed is appalling. However, Holmes does it successfully. But I believe it can not be done except theoretically without great waste of energy and consequent burning of contact surfaces. . . . *But I believe a large voltaic battery will be more economical than any electromagnetic machine.* I am not quite confident about this, but shall be so soon, as I am getting a large voltaic, and I shall soon learn how expensive its habits are, and multiply by the number required for a lighthouse." This was thirty-two years after Faraday had discovered the principle of the dynamo.

In after years Kelvin lost his dread of the commutator and championed direct against alternating current on every possible occasion. In 1879, when giving evidence before a select committee of the House of Commons on electric light, he even assured them that there would be no danger of terrible effects from the employment of electric power, because the currents would be continuous and not alternating.

The fifteen years following 1863 saw a great development of the dynamo, and in 1878, when a paper was read before the Institution of Civil Engineers on the improvements introduced by Siemens, Thomson made a remark, following a suggestion by Dr. C. W. Siemens, that showed that he had by this time thoroughly grasped the possibilities. He said that he believed that with an exceedingly moderate amount of copper it would be possible to carry the electrical energy for one hundred or two hundred or one thousand electric lights to a distance of several hundred miles. Dr. Siemens had mentioned to him that the power of Niagara Falls might be transmitted electrically to a distance, and he need not point out the vast economy to be obtained by the use of such a fall as that of Niagara or the employment of waste coal at the pit's mouth. In his evidence before the select committee referred to above he gave an estimate of

the copper required to transmit 21,000 horse-power from Niagara to a distance of 300 miles.

In 1881 Thomson returned to the subject in his presidential address to section A at York and said, "High potential, as Siemens, I believe, first pointed out, is the essential for good dynamical economy in the electric transmission of power." He mentioned 80,000 volts as a suitable voltage. In a paper before the section he developed the now well-known Kelvin Law of the most economical cross-section of the conductor. In 1890 the American promoters of the project for utilizing the power of Niagara turned to Thomson for his advice, and he became a member of the commission of experts. He was throughout stubbornly opposed to the use of alternating currents; he wrote, "I have no doubt in my own mind but that the high-pressure direct-current system is greatly to be preferred to alternating currents. The fascinating character of the mathematical problems and experimental illustrations presented by the alternating-current system and the facilities which it presents for the distribution of electric light through sparsely populated districts have, I think, tended to lead astray even engineers, who ought to be insensible to everything except estimates of economy and utility." He was in a hopeless minority, however, in this view, and Niagara Falls were harnessed to two-phase alternators with an output of 3,500 kilowatts each. Kelvin was present at the meeting of the British Association held in this city in 1897, and shocked many people by saying that he looked forward to the time when the whole water of Lake Erie would find its way to the lower level of Lake Ontario through machinery; "I do not hope," he said, "that our children's children will ever see the Niagara Cataract." Although he was apparently very much impressed with the success of the Niagara system, he was not converted from his allegiance to direct currents, for at his last appearance at the Institution of Electrical Engineers, in 1907, he said, "I have never swerved from the opinion that the right system for long-distance transmission of power by electricity is the direct-current system."

The development of the dynamo during the seventies and the simultaneous development of the incandescent lamp led to the general introduction of electric light during the eighties. Attempts to make incandescent electric lamps had been made as early as 1841, when de Moleyns patented one having a spiral platinum filament, and in 1847 Grove illuminated the lecture theatre of the Royal Institution with such lamps, the source of power being primary batteries; but it was not until 1878 that the commercial development of the incandescent electric lamp was begun by Edison and Swan.

One of the earliest complete house-lighting installations was put in by Kelvin in 1881. A Clerk gas-engine was used to drive a Sie-

mens dynamo, a battery of Faure cells was fitted up, and every gas-light in his house and laboratory at Glasgow University was replaced by 16 candle-power Swan lamps for 85 volts. He had to design his own switches and fuses, etc., for such things were almost unknown.

For about twenty years the carbon-filament lamp held the field without a rival for interior illumination, and, although attempts were made to improve its efficiency by coating the filament with silicon, the plain carbon filament only gave way finally to the metal-filament lamp. One of the most interesting developments in the history of electric lighting was the Nernst lamp, which was introduced in 1897; the filament consisted of a mixture of zirconia and yttria, and not only had to be heated before it became conducting but also had to be connected in series with a ballast resistance in order that it might burn stably. The way in which these difficulties were surmounted and the lamp, complete with heater, ballast resistance, and automatic cut-out, put on the market in a compact form occupying little more space than the carbon-filament lamp was, in my opinion, a triumph of applied science and industrial research. The efficiency was about double that of the carbon lamp. About this time, however, a return was made to the long-neglected metal filament. The osmium lamp invented by Welsbach in 1898 was put on the market in 1902, to be followed two years later by the tantalum and tungsten lamps. The latter was greatly improved by the discovery in 1909 of the method of producing ductile tungsten and by the subsequent development of gas-filled lamps in which the filament can be run at such a temperature without undue volatilization that the consumption is reduced in the larger sizes to 0.6 watt per mean spherical candle-power. This improvement of eight times as compared with the efficiency of the carbon-filament lamp has led to the gradual replacement of the arc lamp even for outdoor illumination. The arc lamp was introduced at about the same time as the carbon-filament lamp, the Avenue de l'Opéra having been lit with Jablochkoff candles in 1878. The open arc was developed during the eighties; the enclosed arc, giving long burning hours and thus reducing the cost of re-carboning, was introduced in 1893, and the flame arc in 1899. During the first few years of this century the flame arc was brought to a high stage of development and the consumption brought down to about 0.25 watt per candle-power, but the necessity of frequent cleaning to prevent the reduction of efficiency by dirt and the labor of re-carboning have led to its abandonment in favor of the less efficient filament lamp.

Before leaving the subject of electric lighting I would point out that it is remarkable that the first great application of electric power

should have been for the production of electric light, since it is probably the least efficient of all its applications. The overall efficiency of a small power station supplying a lighting load and having therefore a very poor load factor would not be greater than about 6 per cent. from coal to switch board, the steam-engine being, of course, the principal offender. Of the total power supplied to and radiated from a carbon-filament lamp not more than about 2 per cent. was radiated as light, so that the overall efficiency from coal to light was 2 per cent. of 6 per cent., which means that of every ton of coal burned at the power station with the object of producing light all but about 3 lbs. was lost as heat at various stages of the transformation. Even now, with up-to-date steam plant and gas-filled lamps, the overall efficiency from coal to light is not equivalent to more than 40 to 60 lbs. of coal out of each ton. The electrical engineer may derive a little comfort from the knowledge that the purely electrical links are the most efficient in the chain.

Whilst on the subject of efficiency I might point out that the difference between the prices at which coal and electrical energy can be purchased by the ordinary citizen corresponds to the losses incurred in the power station; that is to say that the cost of the generation and distribution of the electrical energy is covered by the better terms on which the power station can obtain fuel. In Glasgow the writer pays £5 per ton for anthracite to burn in a slow-combustion stove; taking the calorific value of anthracite at 9,000 kilowatt-hours per ton, which is equivalent to 14,000 British thermal units per lb., this works out at 7½ kilowatt-hours for a penny. For electrical energy for heating and cooking purposes the writer pays a penny per kilowatt-hour. This ratio of 1 to 7½ will correspond fairly closely to the overall efficiency of the power station. In view of the high efficiency and convenience of slow-combustion stoves, it is evident that electric heating can not be expected to compete with them for continuous operation; for intermittent heating the question is very different.

Returning from this digression to the development of the direct-current dynamo, it may be noted that the drum armature now almost exclusively employed was invented in 1872 by von Hefner Alteneck, and gradually displaced the ring armature of Pacinotti and Gramme. Although Pacinotti's original ring armature was slotted, smooth armatures were preferred for many years, until the mechanical superiority of the slotted armature caused the disappearance of the smooth core with its wooden driving pegs which were employed to transmit the turning moment from the conductors to the core. The commutator and brushes were a great source of trouble, but by the gradual elimination of unsuitable material and

by better design and methods of manufacture the commutator has been made a most reliable piece of apparatus. The difficulties of commutation, and especially the need of continual adjustment of the brush position, were largely overcome by the invention of the carbon brush by Professor George Forbes in 1885. It should be pointed out that the commutating poles, which have come into use so much in recent years, were originally suggested in 1884, and are therefore older than the carbon brush.

The realization of the idea of supplying electric current from a power station for lighting houses in the neighborhood owed much to the energy and business ability of Mr. Edison. He exhibited his first "Jumbo" steam-driven dynamo in 1881, and installed two sets at Holborn Viaduct in the following year to supply current to neighboring premises. The output of these sets was about 90 kilowatts at 110 volts, which was so much larger than anything previously constructed that the name "Jumbo" was applied to these sets. About 1890 the multipolar type began to replace the bipolar type for the larger sizes. The size of the single units employed in power stations gradually increased with the increasing demand, and by 1895 dynamos of 1,500 kilowatts had been installed

As in all other types of machinery, the output obtainable from a given size has been gradually increased by improvements in the electrical, magnetic and mechanical properties of the materials employed, and by improving the design so as to remove ever further the limits imposed by heating, sparking, voltage, drop, etc. The freedom from trouble of the enormous number of electric trams and trains, to take only one class, is a testimonial to the reliability of the modern direct-current motor.

The alternator has had a more varied development than the dynamo, mainly because of the absence of the commutator. The necessity of keeping the brush gear stationary and accessible and therefore allowing the commutator and armature to rotate led to an early standardization of type in the D.C. machine. In the alternator there was no such limitation, and whether the field system should be inside or outside the armature and which of the two should rotate were largely matters of choice. There are great advantages in having the armature, which usually carries a high-voltage winding, stationary, and the usual practice has been for the field system to rotate within the armature. The most striking and best-known exception is the umbrella type of alternator installed in the first Niagara power station, in which the field system rotates outside the armature. The design of alternators has been controlled to a large extent by the development of the prime mover. On the Continent of Europe the slow-speed horizontal steam-engine led

to the construction of alternators of enormous diameter in order to get the necessary peripheral speed, the axial length being consequently reduced to a few inches. In several cases these machines reached such a height that the travelling cranes in the erecting shops were useless, and special tackle had to be erected in order to assemble the machines. In England the high-speed marine-type engine was generally preferred, and consequently the alternators had a smaller number of poles and a smaller diameter. All this has now been modified by the development of the steam turbine.

Ferranti was apparently the first to suggest that the power station should be outside the city, at a point convenient for fuel and water supply, and that the power should be transmitted into the city by high-voltage alternating currents. In 1890 he built the Deptford Station for the London Electric Supply Company, and installed 1,000-kilowatt 10,000-volt alternators. This was the pioneer high-voltage underground cable transmission, and much was learned concerning the peculiarities of alternating currents when transmitted over cables of considerable capacity. The following year, 1891, saw the first long-distance transmission by means of overhead conductors in connection with the electrical exhibition at Frankfort-on-Main; three-phase power was transmitted, at 8,500 volts, from a water-power station at Lauffen to Frankfort, a distance of 110 miles.

This development of the use of high-voltage alternating currents followed the development of the transformer. Gaulard and Gibbs patented a system of distribution involving transformers in 1882, and, although their patent was upset in 1888 on the ground of its impracticability, the present method of using transformers for the distribution of electrical power was introduced in 1885, and shown at the Inventions Exhibition in London in that year. Although from 1890 onwards there has been a steady increase in the size of alternators and transformers and in the voltage employed for long-distance transmission, the last few years have seen a really amazing increase in the size of the units employed. In 1913 the largest 2-pole turbo-alternators had an output at 3,000 revs. per minute of about 7,500 kilowatts; such machines are now made up to 30,000 kilowatts, and 4-pole alternators are running at 1,500 revolutions per minute, with an output of 60,000 kilowatts. This increase in size and in peripheral speed has been made possible by improvements, both in the material and in the design. With a bursting speed 25 per cent. above the running speed, the peripheral speed can now be raised to 150 meters per second. Improved methods of cooling and a better understanding of the various causes of loss in the armature have enabled the materials to be used at higher current and flux densities.

This great increase in the size of units is not confined to the steam turbo-generator, as can be seen from the water-turbine sets recently added to the Niagara installation. Whereas the original Niagara turbines were of about 5,000 horse-power, the new ones have an output of 70,000 horse-power at the low speed of 107 revolutions per minute.

The importance of cheap electric power has led to this great increase in the size of the units in the generating stations. Any slight difference of efficiency between a 10,000-kw. and a 60,000-kw. alternator is of little importance, and would certainly not counterbalance the decreased factor of safety due to concentrating the whole power supply in three or four large units, instead of distributing it between a dozen or more units. The reason for the adoption of the smaller number of large units lies almost entirely in the decreased capital cost per kilowatt of plant. In my opinion, however, there are many cases in which too much consideration has been given to this factor, and too little to the importance of a guaranteed continuity of supply.

Of even greater interest than the growth in the size of the units in the power station is the development of the switch control and protective gear, which is such an essential element in the success of the modern power plant. In the early days of electrical supply all the switch-gear was mounted on slate panels in the engine-room; then, as the power and voltage increased, the switches were placed above, below, or behind the board and operated by mechanical links; then they were removed to another part of the building, each enclosed in its own fire-proof cubicle, and operated by means of relays. The modern high-power switch, like the transformer, is oil-immersed in its iron containing case, and is so robust and weather-proof that it needs no further protective covering, but can be placed in the open air. The insulated bushings through which the leads are taken into the case are the most vulnerable points, but constitute no insuperable difficulty at the present time.

The development of these robust and weather-proof switches and transformers has led to the introduction of the open-air substation in cases where alternating current has to be transformed from one voltage to the other, and there is consequently no running machinery. In generating stations also much of the controlling and transforming plant which was formerly housed in the building can now be placed outside, with considerable saving on the cost of the building.

In connection with the conversion of alternating to direct current, mention should be made of the mercury arc rectifier. Great improvements have been made in recent years, especially in Swit-

zerland, and a number of high-power arcs have been installed in sub-stations. Although they have the advantage of doing away with running machinery, the modern rotary-converter is such a reliable piece of apparatus that it is very questionable whether it will be replaced to any considerable extent by the mercury arc rectifier.

Until recently, the only means of producing a large amount of high-voltage D.C. power was by connecting a large number of carefully insulated dynamos in series, as in the well-known Thury system of power transmission. Within the last two or three years another method has been developed, *viz.*, the so-called transverter, which consists of an arrangement of transformers and a system of rotating brushes, whereby a three-phase A.C. supply is converted into an almost steady continuous current. The first apparatus of this type to be exhibited is installed at the British Empire Exhibition at Wembley, and is designed to deliver continuous current at 100,000 volts. It can also be used for the reverse process. It would thus enable a three-phase generating station and a three-phase substation to be connected by a direct-current transmission line, thus avoiding not only the maximum voltage of 1.4 times the effective voltage, which was one of Lord Kelvin's objections to the A.C. system, but also all trouble due to the capacity and inductance of the line. Whether the disadvantages of the transverter, when it is fully developed—it is yet in its infancy—will more than outweigh these advantages remains to be seen, but, apart from the transmission of power, the device may have many applications.

Electric traction represents one of the most important branches of electrical engineering. It shares with the petrol motor the distinction of having absolutely revolutionized the methods of transport within a single generation. In its origins it is nearly a century old, for attempts were made in the thirties to apply Faraday's newly discovered principle to the propulsion of vehicles, but, with very primitive motors and primary batteries, these attempts were doomed to failure. The development of the dynamo and motor in the seventies opened the way to further experiments, and at the Berlin Exhibition in 1879 a line one third of a mile long was shown in operation, a locomotive drawing three cars. The first regular line was opened to traffic near Berlin in 1881; it worked at 100 volts and the current was collected from an insulated rail. Toronto was the scene of one of the earliest experiments in America; C. J. van Depoele, after some experiments at Chicago in 1882 and 1883, ran an electric locomotive in 1884 between the street-car system and the Exhibition in Toronto.

The difficulties were enormous. The carbon brush was not invented until 1885, and commutation in a reversible motor with

copper brushes caused great trouble; armature construction and winding was in its infancy; the suspension of the motor and the method of gearing it to the car axles were problems which were solved only after much experience. Rapid progress was made after about 1887, and the closing years of the century saw an enormous development, the elimination of horse tram-cars throughout the world and the electrification of a number of city and suburban railways.

Of the various systems of collecting the current, only two have survived for street-cars, *viz*, the usual overhead wire and the exceptional underground conduit, in the case of railways there is no necessity for a conduit and the conductor rail is carried on insulators above the ground-level.

Although 500-volt D.C. supply has been standardized for street tramways, the relative merits of D.C. and A C for electric railways has been a burning topic for over twenty years, and is now perhaps more burning than ever. It is somewhat akin to the battle of the gauges in the early days of steam railways, for it involves in many cases the problem of through running, if not now, in the not very distant future. Although the three-phase system was successfully installed in Northern Italy, it has grave disadvantages, and the battle now is confined between direct current at an increased voltage of, say, 1,500 to 2,000 volts, and single-phase alternating current. In the latter case there is, moreover, a further question as to the best frequency to adopt, this being usually either 25 or 16 2/3. The development of the A.C. commutator motor to the stage where it was applicable to traction took place during the first few years of this century, and, although in itself it is inferior to the D.C. motor, it introduces so many simplifications and economies in the transmission of the power from the generating station to the train that experts are very divided as to the relative merits of the two systems for main-line electrification.

I can only just refer to the applications of electrical power to chemical and metallurgical processes. Some of these are purely electro-chemical, others are purely thermal, while in many processes the electric current performs the double function of melting and electrolysing. The possibility of electroplating was discovered as early as 1805, but the commercial application of electro-chemistry on a large scale was impossible before the development of the dynamo. Within the last thirty years the provision of an abundant supply of electrical power has led to the creation of enormous electro-chemical industries; I need only instance the production of aluminium, carborundum and calcium carbide. These industries have usually been established near a hydro-electric plant and provide a load of very high load-factor.

I turn now to what may be called both the earliest and the latest application of electricity; that is, its use for transmitting intelligence. One of the greatest factors in the development of our modern life has undoubtedly been the network of wires and cables which has spread over the whole earth, making possible an almost instantaneous transmission of intelligence and interchange of opinions. In the early days of electrical science the discovery of a new property of electricity was followed by attempts to utilize it for this purpose As early as 1746 there are records of the use of frictional electricity for the purpose, and distances up to four miles were tried. In 1774 Lesage of Geneva proposed 26 wires in earthenware pipes with pairs of pith-balls at the end of each wire, which flew apart when the conductor of a frictional machine was brought near the other end of the wire. A current of electricity was unknown until Galvani's discovery in 1789, and Volta's pile was first constructed in 1792. Carlisle in 1800 found that water was decomposed by passing the current from a Volta pile through it, and this was the basis of the telegraph proposed by Sömmering in 1809, in which 26 wires ended in 26 metallic points arranged in a row along the bottom of a kind of aquarium. By means of a lettered keyboard at the sending end the current could be applied to any wire, and a stream of bubbles caused to rise from the appropriate point, each point being duly labelled with its appropriate letter. The magnetic effect of the electric current was discovered in 1819, and immediately replaced the previous methods in efforts to develop an electric telegraph; except for the attempts to make a high-speed chemical telegraph, all subsequent telegraph systems have employed the magnetic effect of the current. A great many of the fundamental inventions of telegraphy were made in the thirties; the list includes the needle instrument of Cooke and Wheatstone, the sounder of Henry, the dot-and-dash inker of Morse, and the use of the earth as a return by Steinheil. Although the needle instrument is now obsolete, the sounder and Morse inker are still commonly employed. Many have been the devices for increasing the amount of traffic which can be worked over a single line, either by the simultaneous use of the line by a number of operators, as in the quadruplex and multiplex systems, or by punching the messages on paper tapes, which can then be fed into an automatic transmitter working at a speed ten to twenty times that attainable by a manual operator. In the most up-to-date systems the perforation of the tape is done by the operators working an ordinary typewriter keyboard, and the received message is printed in ordinary type, a single wire carrying eight messages simultaneously, four in either direction, at a speed of 40 words per minute.

The need for telegraphic communication between countries separated by water was so much the greater because of the slowness of other means of communication, but the difficulties in laying and maintaining 2,000 miles of insulated wire on the bottom of the sea must have appeared almost insuperable to the early workers; fortunately, however, there were men who had the necessary vision and courage. The flimsiness of the early cables suggests that the pioneers underestimated the magnitude of the problem which faced them, which was perhaps fortunate. A cable was laid between Dover and Calais in 1850; it lived only a single day, but it was replaced in the following year by a successful cable.

The first cable was laid across the Atlantic in 1858, and, although in the light of our present knowledge we know that it could not have had a very long life, its failure after a few weeks of preliminary communication was primarily due to misuse owing to the ignorance of those in charge. Although much costly experience had been gained in the laying of cables in various parts of the world since this first attempt to span the Atlantic, the success of the second Atlantic cable in 1866 was largely due to the scientific ability of Kelvin and to his enthusiastic and untiring application to the project at every stage of the manufacture and laying of the cable. In addition to this, he not only designed the receiving instruments, but superintended their manufacture in Glasgow and their installation and operation. The success of the Atlantic cable was to a large extent a personal triumph for Lord Kelvin. Although numerous improvements have been made in the details of cable manufacture and in the transmitting and receiving apparatus, no outstanding change has been made in recent years in the method of submarine telegraphy.

Turning to another branch of electrical communication, it is no exaggeration to say that modern business life has been revolutionized by the telephone, which will shortly celebrate its jubilee, for it was in 1876 that Graham Bell invented the magnetic telephone receiver, although others, notably Reis, had been working at the problem since 1861. Bell showed his telephone in operation at the Philadelphia Centennial Exhibition in 1876, and Kelvin, who was one of the judges, brought one back with him and demonstrated it to section A of the British Association, at its meeting in Glasgow in the autumn of 1876.

A successful telephone system requires much more than efficient transmitters and receivers, and the great development which has taken place has been largely a matter of improvement in the design of the many elements that go to make up a telephone exchange. The modern manual central-battery exchange, in which one has

only to lift his receiver to call the operator and be connected in a few seconds to any one of 10,000 other subscribers, is a marvel of ingenuity and construction. But this is now gradually being replaced by the greater marvel of the automatic system, in which the operator is eliminated and the subscriber automatically makes his own connection to the desired subscriber. Attention should be drawn to two outstanding inventions in the actual transmission of telephony over long distances, *viz.*, loading and repeaters. It was Oliver Heaviside who in 1885 proposed to improve the range by increasing the inductance of the line. Although this revolutionary suggestion fell on deaf ears for fifteen years, it ultimately proved to be one of the great inventions of telephony; it is of special importance in underground and submarine telephone cables, the electrostatic capacity of which otherwise seriously limits the range. The other outstanding novelty is the introduction of repeaters at intermediate points in long telephone lines. These repeaters are specialized types of low-frequency amplifiers; they were made commercially possible by the invention and perfection of the three-electrode thermionic valve. The attenuated speech currents arriving at the end of a section of line are amplified and thus given a new lease of life before being passed on to the new section. By using a large number of such repeating stations, telephonic communication has been established between New York and San Francisco. But in addition to making such long-distance communication possible, the use of repeaters enables medium distances to be bridged by relatively cheap lines of high attenuation.

One important application of telephony which is not generally known is in the control of transport; the advantage to be gained by controlling the whole railway traffic of a large district from a central office need only be mentioned to be appreciated.

Turning now to radio telegraphy and telephony, one can not but marvel at the rapidity of its development and the inroad that it has made during the last two or three years on the domestic life of the whole civilized world. The theory of Clerk Maxwell in 1864 and the laboratory experiments of Hertz in 1888 found their first practical application in Marconi's Italian experiments in 1895 and his demonstrations in England during the following year. Much of the rapid progress was due to his perseverance, vision and courage in perfecting apparatus for short-distance work, and simultaneously experimenting over long distances, and thus, in the year 1901, settling by actual demonstration across the Atlantic the vexed question as to whether the waves would pass around the earth over distances of several thousand kilometers or go off into space.

The accomplishment of long-distance communication bristled with difficulties, largely due to unsuspected atmospheric effects

which are still little understood; but such progress has been made and is continually being made that one dare not now adopt an incredulous attitude to the wildest dreams or forecasts of what is to be accomplished by "wireless." The commonplace facts of to-day would have appeared beyond the bounds of possibility ten or twenty years ago.

I have attempted to trace, in a necessarily somewhat superficial, but, I trust, none the less interesting, manner the development during the last hundred years of some of the principal applications of electricity to the service of mankind. In preparing this address, I have been greatly impressed by the enormous advances made, especially during the last thirty or forty years, in the mastery of man over the resources of nature, and in the use of these resources to the amelioration of the conditions of life. By the aid of electricity the energy of the coal or of the lake or river a hundred or even two hundred miles away is transmitted noiselessly and invisibly to the city, to supply light and warmth, to cook the food, to drive the machinery, to operate the street-cars and railways.

By its aid one can flash intelligence to the most distant part of the globe, hold conversations with friends hundreds or even thousands of miles away, or sit in one's home and listen to music and lectures broadcast for the entertainment or instruction of all who care to equip themselves with what may almost be regarded as a new sense. Whereas thirty years ago a ship at sea was completely isolated from the life and thought of the world, it is now in continuous communication with the land and with every other ship within a wide range.

In no branch of electrical engineering, however, is there any suggestion of having reached finality; on the contrary, rapid development is taking place in every direction, and we can look forward with confidence to an ever-increasing application of electricity to the utilization and distribution of the natural sources of energy for the benefit of mankind.

PURPOSIVE STRIVING AS A FUNDAMENTAL CATEGORY OF PSYCHOLOGY[1]

By Professor WILLIAM McDOUGALL

WE who are workers in the various fields of psychology are happy in the knowledge that our science is rapidly developing, extending its influence into every sphere of human activity. The institution and the success of this section of the British Association are good evidence that our colleagues in the other branches of natural science have recognized the claim of psychology to take its place among those other branches. And, though in Great Britain there are still all too few chairs of psychology, in Canada and America the universities and colleges are now providing abundant opportunities for teachers, students and research workers, opportunities that are being eagerly and fully used.

Yet, in spite of this happy state of affairs, there is manifested among us psychologists a certain uneasiness as to the status of our science, an anxiety lest the psychologist be regarded as not quite really and truly a man of science. This anxiety is, I think, exerting an unfortunate influence on the development of our science, an influence which shows itself in two principal directions

On the one hand is a group of psychologists, who, actuated by the desire to mark off an exclusive field of study as their province, define psychology as the science of consciousness and would confine themselves to the analytic description of conscious states as complex conjunctions of elements or units of some kind. On the other hand are those who, feeling that such analytic description, whether it resolves consciousness into a complex of sensations or atoms of consciousness, or into larger more complex units (the so-called configurations or *Gestalten*), brings but little light on human nature and conduct, and can hardly claim to be in itself a science, are driven to the opposite extreme; they ignore this realm of facts, alleged to be the peculiar and distinctive field of psychology, and they would bring to the study of man only those methods of observation, description and explanation which are used in the physical sciences. These two tendencies, which, when they are carried to extremes result respectively in what is unfortunately called "structural psychology" and in "behaviorism," although so different in their outcome, are but two expressions of one desire, the desire to

[1] Address of the president of the Section of Psychology of the British Association for the Advancement of Science, Toronto, August, 1924.

make psychology conform to some preconceived notion of what a science is or should be. The "structuralist" aims at marking out a peculiar and exclusive field of objects of study. The "behaviorist" slavishly accepts the physical sciences as his model, and seeks safety from the charge of being unscientific by confining himself to the use of the methods of observation, description and explanation current in those sciences

Although a very considerable number of psychologists are following these two widely divergent lines (especially, perhaps, in America), I may, I think, take it for granted that to the majority of us neither line is satisfactory. We feel that both are the expression of a lack of courage; of an undue timidity. In face of the imposing edifice of the physical sciences, the one party shrinks back and seeks to define a little field of knowledge altogether peculiar to itself, within which the psychologist can disport himself at his own sweet will without fear of collision or conflict with the other sciences; the other party seeks safety by taking cover in the bosom of the herd, carefully avoiding all speech or action that might, by marking him as a distinctive variety of the species scientist, bring upon him the suspicious glances of other members of the herd.

There is yet a third large group of psychologists who, moved by the same desire as these others, yet seeing that neither group achieves, nor can hope to achieve, a satisfactory science of human nature and conduct, seek to escape from the limitations of both groups by combining the procedures and the conclusions of both. These adopt the analytic description of consciousness (whether of the "sensationists" or the "configurationists") and they accept the mechanistic explanation of conduct of the "behaviorists;" and they seek (by the aid of the principle of psycho-physical parallelism or of epiphenomenalism) to put the two together in parallel columns, to form what can only be called a lame apology for a science.

The very fact that this undue timidity has produced these two widely divergent and aberrant (not to say abortive) types of psychology is its sufficient condemnation. We should take warning from it; we should be led by it to see that a policy of courage is also the policy of safety. I urge that we psychologists are now numerous enough and strong enough to stand together, to form our own herd, a herd in which our more timid members may find the shelter which they crave. In other words, I urge that the time has come when the students of human nature should boldly claim autonomy or, at any rate, dominion-status for their science; they should invoke and boldly apply the principle of self-determination.

I urge that this policy of safety through boldness is justified and demanded at the present time by considerations of three kinds,

in addition to the fact of the unsatisfactory results of the policy of timidity which I have already indicated

First, psychology has now at its command an immense mass of data, facts of introspective observation and facts of behavior, demanding to be synthesized in our science, not merely to be placed side by side in parallel columns.

Secondly, psychology has found many important fields of application, in education, in medicine, in industry, in the social sciences, and all these require a psychology, a science of human nature, very different from the mere description of consciousness and from the mechanistic explanation of behavior and different also from the parallel-column psychology.

Thirdly, the policy of boldness is abundantly justified by the present state of the other natural sciences.

I propose to dwell briefly upon each of the three classes of consideration in turn And in relation to each I desire to urge that the most fundamental need of psychology, the first demand to be met by the policy of boldness, is the adoption without reserve of the conception of purposive striving as valid, useful, nay, indispensable and therefore true.

The life of man from birth to death is one long series of purposive strivings. Sometimes, as when he plans his career and sets out to build up a home and a family, his goal is remote and somewhat vague, defined in his mind in general terms only, sometimes it is precisely and exactly defined, as when he goes to eat his favorite dinner at his favorite table in his club; sometimes it is near and yet but vaguely defined, as when, with open mouth and feeble movements of head and trunk, he seeks the nipple of his mother's breast; or when, during an absorbing after-dinner conversation, he reaches out to put a piece of candy in his mouth. There is a vast range of differences in respect of the nearness or remoteness of the goal; and in respect also of the clearness, fullness and adequacy with which he thinks of his goal. And there is also a wide range of differences between his successive strivings in a third respect, namely, in respect of the urgency, the intensity, the concentration and output of energy manifested in his striving at any movement. Yet, in spite of these wide differences, the striving is always one aspect of his waking life. And even in his dreams, as we now realize, thanks to Professor Freud, the striving goes on, bringing what strange and partial satisfactions it may to the buried, thwarted and denied tendencies of his nature. From top to bottom of this scale of strivings we have to do with the same fundamental phenomenon. In the instances near the top, the more developed modes of mental life, involving the solving of a defined problem, the

thinking out of a plan, we all recognize the purposive nature of the striving. The goal, as envisaged, governs the movements of both mind and body.

In instances at the lower end of the scale, introspection or rather retrospection, inevitably fails to seize and report the thinking of the goal as distinct from the perceiving of the situation of the moment. Yet the continuity of the series justifies us in regarding its lower members as fundamentally of the same nature as its upper members and in applying the term "purposive" to them all alike.

Even in laboratory experiment, where the conditions are commonly so set as to reduce the striving factor to a dead level of uniformity and monotony, it refuses to be ignored forever; and so, after a generation of experimentation that ignored it, it is rediscovered and reinstalled in its place of fundamental importance, disguised under some such terminology as "determining tendency" or "motor set" or "conditioned reflex" or "prepotent reflex" or what not.

Under all three of the types of psychology we have noticed, this most vital, essential, distinctive aspect of human life escapes the psychologist. For it can not be described as either a sensation or a configuration (*Gestalt*). And it is not to be discerned by an inspection of the detailed movements of the limbs or of other bodily organs, no matter how exact.

Nor can it be restored or recovered in the psychology of parallel columns. It can be discerned in others only by sympathetic observation and interpretation of the course of their lives. If, under the influence of any metaphysical dogma or any supposed rule of method, you overlook it from the start, you can not introduce it into your otherwise completed picture of human nature, as an element to be added to and put alongside others already described.

It is too all-pervasive for such treatment. As well might the landscape artist, after painting a picture without atmosphere, attempt to add it by drawing a smear of paint across the whole. This is the difficulty found by students who have been brought up on the parallel-column psychology, as I know from instances of such students who have found difficulty with my frankly purposive "Outline of Psychology"; nor are such students helped to a truer view of human nature by those books on psychology which, after describing man after one or other of the three fashions we have noted, throw in perfunctorily as an afterthought a chapter on "The will." If striving has been ignored throughout the composition, "The will" can not be added to the picture as a finishing touch. Having learned to look upon man as a bundle of mechanical reflexes, a superior penny-in-the-slot machine, whose workings are

mysteriously accompanied by various "elements of consciousness," they can find no place in their completed picture for yet another element called "a purpose"; it refuses to fit in among the other blocks; there is no room for it, and, as they think, no need for it; and it seems to them quite an ambiguous, not to say shady and suspicious, character; at best it appears to them as a disturbing intruder.

But let the budding psychologist ponder some phase of human life that is dominated by some strong but thwarted desire. Let him consider the strange yet familiar case of Romeo seeking the Juliet who is forbidden to him. How this desire to see, to hear, to touch the loved one dominates his life, waking and sleeping! How it fevers his blood; wears him to a shadow; keeps him running to and fro, scheming, trying, hoping, desponding, exulting, despairing and always desiring! The desire governs all his thinking and acting; the most rooted habits and mental associations are as nothing in the course of this torrent of purposive activity, all directed to Nature's most imperative goal.

Can we accept any account, any description or explanation of human life which leaves out of the picture this all-important aspect that we call impulse, desire, striving towards a goal?

When we turn to the fields of applied psychology, the same truth stares us in the face. In every field we find that the most urgent practical problems are concerned with the striving aspect of human nature. The most fundamental task of the educator is to awaken an interest in and a desire for knowledge and self-development. The psychiatrist must study and redirect if possible the conflicting desires of his patient, his subconscious as well as his conscious motives and impulses.

The personnel manager is chiefly concerned with incentives, rewards, jealousies, rivalries, discontents, loyalties, ambitions and aspirations. The lawyer, the judge and the jurymen are primarily concerned to determine motives, intentions and responsibility. The politician, the economist and the moralist are, or should be, primarily concerned with relative values and the means to make real or actual the highest values of mankind by harmonizing and coordinating the conflicting motives of our social life.

In all these cases a psychology that ignores the all-pervading purposiveness of human life is of no use; for, if it is consistent, important words that are essential to the intelligent discussion of human affairs (such words as motive, intention, desire, will, responsibility, aspiration, ideal, striving, effort, interest) are of no meaning for it; or, if they are used, are used with a meaning so thin and so different from that of ordinary discourse, that profitable converse with the practical man is impossible.

I leave that large topic with these few words and pass to my third consideration in support of the policy of boldness. Thirty to forty years ago when I began to study science, considerable moral courage would have been required to insist upon the purposive nature of man. For at that time the great wave of scientific materialism was still but little past its climax. It was the day of Spencer and Huxley, of Clifford and Tyndal, of Lange and Weismann, of Verworn and Bain. The world and all the living things in it were presented to us with so much prestige and confidence, as one vast system of mechanistic determination, that one seemed to be placed before two acutely opposed alternatives: on the one hand, science and universal mechanism; on the other hand, humanism, religion, mysticism and superstition.

But to-day how different is the situation! Even at the date I speak of, a few great physicists warned us against regarding the principles of physical science as adequate to the interpretation of human life. And to-day those few voices have swelled to a chorus which even the deafest biologist can hardly ignore Einstein and Eddington and Soddy and a score of others repeat the warnings of Maxwell and Kelvin and Poynting and Rayleigh And the physical universe of eternal hard atoms and universal elastic ether, the realm of pure mechanics, has become a welter of entities and activities which change and develop and disappear like the figures of the kaleidoscope The psychologist who would believe in the efficiency of human effort no longer needs to fling himself in vain against the problem—How can Mind deflect an atom from its predetermined course? For the atoms are gone; matter has resolved itself into energy, and what energy is no man can tell, beyond saying—it is the possibility of change, of further evolution.

In physiology the mechanistic confidence of the nineteenth century is fading away, as the complexity of the living organism is more fully realized, as its powers of compensation, self-regulation, reproduction and repair are more fully explored.

In general biology the mechanistic Neo-Darwinism is bankrupt before the problems of evolution, the origin of variations and mutations, the differentiation and specialization of instincts, the increasing rôle of intelligent adaptation, the predominance of mind in the later stages of the evolutionary process, the indications of purposive striving at even the lowest levels, the combination of marvellous persistency of type with indefinite plasticity which pervades the realm of life and which finds its only analogue in the steadfast purposive adaptive striving of a resolute personality.

All these considerations, I say, should encourage us to claim autonomy for psychology, the right to choose, shape and refine its

own fundamental conceptions. We should now easily find the courage to be anthropomorphic in describing man. Instead of accepting the abstract conceptions of physical science and attempting to build up from them a plausible mechanical dummy which shall stand for man in our science, let us frankly acknowledge that man is that thing in all the world with which we have the most intimate acquaintance Let us begin by accepting him for what he seems to be, a thinking being that strives to attain the goals he desires, to realize his ideals, sometimes succeeding, often failing but always striving so long as he lives. Let us try to understand the history of these tendencies to strive as they are revealed in the individual and the species; to understand more nearly our knowing, our imagining, our recollecting, our judging and reasoning as they serve us in our strivings for the attainment of our goals.

As we progress with this task, let us cautiously extend the same principles of explanation to the animals of successively lower levels. And, when in this way we shall have gained some understanding of the life of the animalcule, we shall, perhaps, be able to begin to understand the physiology of the complex organism in its broader aspects. Instead of trying to illuminate human society by likening it to an animal mechanism, as was the fashion of the nineteenth century, we may find that we can profitably invert the process, that we can illuminate the complex organism by likening it to a well-organized harmonious human society, a society which can adjust itself to a thousand disturbances and can recover itself from grave disorders just because and in so far as each member, endowed with limited powers of adaptation, steadfastly strives always to achieve the goal prescribed by his own nature and by his active relations with all his fellow-citizens.

But here we shall be met again by the cry of the timid psychologist. "You are not scientific," he will say, "for you are disregarding the fundamental postulate of all science, namely, that all events are strictly determined, that mechanistic causation rules universally." To this we can only reply by exhorting him once more to have courage, assuring him that "Not all propositions made by all philosophers are true, neither does a proposition become true through being frequently repeated."

Let us be content to postpone metaphysics and to start out from two indisputable empirical facts: first, the fact that sometimes men create new things, such as great works of art and literature and new scientific formulae. Secondly, the fact that, when the normal man simply and strongly desires a certain end and perceives certain bodily movements to be means to that end, those movements follow upon that desire and that perception. Here are well-established

empirical generalizations from which we may confidently start out, refusing to be held up by questions at present insoluble, such as—How can consciousness deflect the path of a single molecule in my brain? Answers to such questions are quite unnecessary as foundations for purposive psychology. It is in the highest degree probable that as science progresses it will become clear that such insoluble questions have been wrongly stated and should never have been asked.

Let us not deny ourselves the right to build up a psychology that may be of use and value to our fellow-workers in the social sciences, because we can not at present answer the most difficult of all questions. The physicist is equally non-plussed if you ask him comparable questions, such as—how does one molecule attract or repel another? What is the nature of chemical affinity? What is electricity? But he does not suspend his researches because his fundamental conceptions and assumptions are disputable and disputed, nor does he turn to some other branch of science in order to borrow from it others that have more prestige. Let us follow his example.

Let us gather our facts of human nature by objective and by introspective observation. Let us make our empirical generalizations and correlations of these facts, building up our own science in our own way. Let us boldly affirm that, just as the physical sciences do not proceed deductively from any system of exact abstract propositions, so also psychology, the most concrete of the sciences, is not required by any higher authority to accept or formulate any abstract propositions as an unchanging deductive basis.

It may be that eventually men of science will agree that there are in the universe two ultimately different kinds of process, the mechanistic and the purposive, the strictly determined and the creative, the physical and the mental. Or it may be that, eventually one of these may be shown to be merely an appearance of the other, an appearance due to the present limitations and imperfections of our understanding. At present we can not decide this issue.

But, if I attempt to guess at the future development of science, I incline to follow the lead of the most powerful intellects of all ages, and to predict that, if such resolution of the two types of process into one shall ever be achieved, the purposive type that we regard as the expression of mind will be found to be more real than the other.

THE DATE-PALM IN ANTIQUITY

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"HONOR your paternal aunt, the date-palm," the prophet Muhammad enjoined his followers. "I call it your paternal aunt because it was created out of the earth left over after the creation of Adam (on whom be peace)."

Whether this account of the origin of *Phoenix dactylifera* Linn. be accurate in detail or not, it is certain that at the dawn of history the date-palm is found established and cultivated in the subtropical zone from Western India to the Atlantic Ocean, and that since the beginning of written records it has been prominent as a means of sustenance, a source of material for manufactures, a fount of beverages and an object of worship for many peoples.

Some millions of years ago, the genus not only extended into Northern Europe, but occurred in North America as well. It would be difficult, on the basis of the material available, to relate the various fossil forms of Phoenix-like palms to any one modern species of Phoenix rather than another. They therefore throw little light on the much debated question of the locality in which the cultivated date-palm first appeared. It has been accredited by one student or another to almost every part of its present range. So far as one may safely speculate on the data furnished by the present distribution of the genus, it appears to me that the reasoning of O. Beccari is sound.

In the first place, he says, the home of the entire genus must be located, and he believes this to be India. While the distribution of known fossil remains does not bear out this conclusion, it may be replied that the fossils of the orient have been little studied, compared with those of Europe, and, if search were made, abundant evidence might be found of Phoenix in the orient. In any event, the distribution of the existing species, and their affinities, may be fairly interpreted to support the oriental origin of the genus, as against an African, European or American origin.

Next, the home of the date-palm must be more definitely located by a consideration of its characteristics. It is a plant that thrives best in subtropical regions with scanty rains or none at all; yet it demands abundant and constant moisture about its roots. The seeds not only require wet soil in which to germinate, but the cotyledon has no less than four well-marked features adapting it

to resist excessive moisture, and the roots of the seedling possess as many similar peculiarities, according to G. Firtsch. These features can be reasonably explained as showing that the seedling is adapted to grow in water-logged soil. Moreover, the species is remarkably tolerant of salt water and alkalis.

Dr Beccari interprets these facts, plausibly enough, to mean that the date-palm originated in a country where the air was hot and dry but the ground sodden with salt water. Where can these conditions be met so well as on a subtropical seacoast?

If India be accepted as the home of the genus, then this particular species must have taken its origin somewhere on the margin of the generic home, for the greater part of India will not meet the requirements above laid down In extreme northwestern India, and beyond, along the shores of the Persian Gulf, is a region that exactly fills the specifications. Here, then, the ancestral home of the date-palm may be placed with some assurance.

But speculation about something that happened so long ago is more interesting than certain. It is certain that the date-palm is not to be found wild at the present time on the shores of the Persian Gulf, or anywhere else. The wild palms that have been reported from various parts of the world must be regarded as escaped or naturalized. The fruit is so easily transported and the seeds, thrown aside by a traveler or carried long distances to be dropped in the excreta of animals, germinate so readily that it is easy to account for the presence of the palm in even the most remote spot. It can grow only near water, and as a water supply in the desert is prized above everything else, and certain to be visited from time to time, no matter how remote from civilization, it can rarely happen that any palm is left entirely to itself for many years. All the uncultivated palms of which I have ever heard, in the most remote fastnesses of Arabia or the Sahara, are visited at least in the fall by nomads who gather the ripe dates.

Like many other cultivated plants and domesticated animals, then, the date-palm to-day represents a human product, long removed from and somewhat altered from its ancestral condition, whatever that may have been.

From India I have found few records indicating the importance of the date-palm at an early period, although the Sanskrit language is well supplied with indigenous names for it. The species is naturalized in Sindh, where there are two local legends regarding its origin: (1) That dates formed part of the commissariat of Alexander the Great, when he invaded the country in 327 B. C., and that the present groves sprang from seeds thrown away by his soldiers, and (2) that the fruit was introduced by the Arab con-

querors of Multan and Sindh in the seventh century A. D. Of course neither of these legends is to be taken seriously: It can hardly be doubted that the date-palm has been at home in northwestern India since prehistoric times, although it has never been brought to a high state of culture there.

The oldest written records are found in Babylonia. Scholars are now generally agreed that no really historical settlement in the plain of the Tigris and Euphrates rivers can be traced with certainty much before 5000 B. C., but it is likely that the palm was cultivated there for several thousand years previously. The first historical records, which do not go back much farther than 4000 B. C., show civilization already far advanced.

Obviously, the cultivation of the palm can not be dated very far back in the Tigris-Euphrates delta, where it now finds its greatest commercial development, for the reason that this alluvium itself is relatively recent, having been laid down not earlier than 10000 B. C. in all probability. The culture of the palm may have been brought into the delta from Arabia; or from northern Mesopotamia, where A. T. Clay thinks the ancestors of the Babylonians learned the art of irrigation, or it may have come in from the gulf coast of Persia. I have found little record of it in the antiquity of the last-named country. But no matter whence it came, it is a safe inference that it had already begun to play an important part in the life of the people who cultivated it

Dr. Beccari has pointed out that in at least four respects the palm had a peculiarly intimate relation to the primitive date growers:

(1) It produced a large supply of the best possible food, easily stored or transported, and therefore adapted to give its possessors a notable advantage over their neighbors.

(2) It furnished a rich source of material for building and home industry, to the extent of satisfying a large part of the requirements of its owners. Strabo refers to an old Persian hymn which enumerated 360 different uses of the palm.

(3) It furnished an intoxicating beverage, called in cuneiform inscriptions "the Drink of Life." The way in which this could have come into use is interestingly conjectured. "That primitive man could at a very early period discover the manner of obtaining a fermentable liquor from the date-palm is easily understood," Dr. Beccari remarks. "When he learned that by cutting out the terminal bud of the palm he obtained a delicious food, he also found that as a result of that operation a sweetish liquid flowed abundantly from the wound. Nothing more natural, in a country where water is scarce, than that this liquid should have been caught

in some kind of a receptacle and used for drinking. But in the meantime the liquor fermented: and thus, perchance, earlier than the juice of the grape, man may have learned the method of making alcohol, and felt the effects of its inebriating power."

Dr. Beccari might well have emphasized even more strongly the tremendous importance this discovery must have had as an agent of natural selection of humankind While palm wine is not to be compared, in alcoholic content, with distilled liquors, it yet contains enough alcohol to be dangerous, when fermented. The French government had to prohibit its manufacture in Algeria, partly because the bibulous Berbers were destroying their plantations in order to gratify their craving for stimulants, but largely because the beverage led to incessant breaches of the peace. The influence of alcohol in injuring the human body is to-day well recognized: yet most of the people now exposed to it are the product of many centuries of natural selection, when the least resistant drank themselves to death and only the stronger survived to become the ancestors of the present generation. The havoc that might have been wrought by palm wine, when first discovered and used by a people who had never undergone any selection against alcohol, can only be imagined by remembering how the American Indian has fared under similar circumstances.

(4) Added to its value as a producer of food, drink and shelter, the date-palm possesses another element of intense interest to the primitive mind, in the separation of its sexes on different plants. The mystery of reproduction always appeals strongly to the imagination of primitive people—as indeed it does in somewhat different ways to more sophisticated populations—and here was a particularly striking case, where the process of fecundation could be watched or even carried out by the agency of man, and where the difference of result, as the female was or was not pollinated, was marked. Moreover, the subsequent development of the embryo was more visible than it is in the higher animals. The useful date-palm, already revered as a storehouse of delicious food and a fountain of the drink of life, came to symbolize the creative force of nature, and to be in some cases the object as well as the symbol of worship. It gradually became identified (as has been skilfully shown by George A. Barton) with the primitive Semitic goddess, later personified as Ishtar or Astarte, who particularly embodied nature's creative forces.

In short, the paternal aunt had made her way into the Pantheon.

The earliest records of the palm cult show it centered at Eridu, only a few miles from that Ur of the Chaldees (Mughair of modern maps) whence Abram migrated to Palestine; and now 90 miles

from the head of the Persian Gulf. It was then a seaport, however, and calculations of the rate of silt deposition indicate that this must have been about 7000 B. C. It may be that this was the first station occupied by the invading Semites, coming north out of Arabia, and it is a plausible conjecture that they stopped here because they found their old friend, the date-palm, already in possession of the ground.

Here, at a somewhat later date, was a famous oracle tree, known as the Tree of Life, whose position in a garden near the town marked the center of the world. This tree was a date-palm. A fragment of an old hymn has been preserved, which tells something of this institution:

In Eridu a palm-stem grew overshadowing: in a holy place did it become green;
its root was of bright lapis lazuli which stretched toward the deep: [before] the god Ea was its growth in Eridu, teeming with fertility:
its seat was the [central] place of the earth; its foliage was the couch of Zikum, the [primeval] mother.
Into the heart of the holy house which spread its shade like a forest hath no man entered.
[There is the Home] of the mighty mother who passes across the sky.
[In] the midst of it was the god Tammuz.

As the translator, A. H. Sayce, explains, "The sacred tree whose branches reached the heaven while its roots were nourished by the primeval deep was the tree which supported the world. It was emphatically a Tree of Life and is accordingly represented time after time on the monuments of Babylonia and Assyria."

The palm cult rapidly became widespread and organized It extended gradually northward, reaching Phoenicia and Syria; residents of the former region carried it to the western Mediterranean, as will be described later. In all these regions the Tree of Life, the date-palm, became a conventional factor in decorative art, reaching its greatest vogue, perhaps in the kingdom of Assyria about the ninth century before the Christian era, when the huge palaces of Nimrod (Nineveh) were constructed, in which the palm and the palm god figure at every turn.

In general, the sacred palm was depicted in the interior decoration of temples, on city gates, royal vestments, seal cylinders and anywhere else that the ingenuity of the artist could work it in. Early representations show the palm god as a human figure with palm leaves attached to her shoulders like wings; later these leaves were conventionalized into feathers, as being more suitable for a member of the animal kingdom, and the god appears with a pair of avian wings. The paternal aunt is now a full-fledged divinity.

The plain of the Tigris and Euphrates rivers, where the worship of the palm originated, was known to its early dwellers as Edin, and it was long ago suggested that the Biblical legend of the Garden of Eden, with its sacred trees, is but a version of Babylonian legends concerning the palm god "The garden with the Tree of Life in the midst was planted 'in Eden, eastward,' for such is the correct rendering of the Hebrew text," declares Dr. Sayce, "and not 'eastward in Eden,' as the Authorized Version has it Not only the garden, but Eden also, lay to the east of the land where the writer lived The garden stood hard by Eridu, 'the good city,' and thus in the very region where the salt 'river' of the Persian Gulf was divided into its four heads," mentioned in *Genesis* ii, 10–14. The Tree of Knowledge of Good and Evil, mentioned more prominently in the Biblical account, must be regarded as derived from the interpolation of a second legend. Whatever the latter tree may have been, it is fairly clear that the Tree of Life represented the date-palm; and this supposition is distinctly confirmed by the Apocrypha In the oldest portion of the Ethiopian Book of Enoch (Chapter 24) it is related that the prophet visited Paradise and found the Tree of Life itself—and it was a date-palm.

The sacred character of the palm involved various corollaries· for instance, among the ancient Assyrians it was bad luck to walk between two palms growing close together; while dates were tabu at times and to eat them on forbidden days was thought to bring on ophthalmia.

Presumably the dates grown by early cultivators were inferior berries with large seeds and little flesh, like the fruit of many seedling palms to-day, or like that of the wild Indian species, *P. sylvestris* Roxbg. But amelioration by the selection of superior seedlings and propagation of them by offshoots took place before the beginning of history. By the time of Hammurabi (about 1958–1916 B. C.), palm-growing was established on a sound basis as one of the principal agricultural occupations of Babylonia. The sixtieth paragraph of that monarch's famous code of laws provides that, if a man lease his garden to another to plant as an orchard, he shall let it without rent for four years, but in the fifth year the owner shall have half the fruit. There are several contracts of the period of Hammurabi which relate to orchards, all of which mention dates as the only fruit crop. The natural inference is that a Babylonian orchard was a date orchard, and that planting an orchard meant bringing palms to bearing. Four years, then, was the time allowed for this—a limit that calls for skilful propagation. Indeed, if the Babylonians could get a crop of dates in the fifth

year, they did better than their present-day successors in that region.

In the archives of the temple library at Nippur, dating not many centuries after Hammurabi, Edward Chiera tells me that he has found a list of some 20 distinct horticultural varieties of date-palm, with particulars as to the yield of each one. Such a status argues a great antiquity for the culture.

In Egypt the palm likewise seems to have existed from prehistoric times and may have been found there by the ancestors of the old Egyptians, when they themselves migrated into the Nile valley. Presumably it was cultivated by the pre-Egyptian population, and its fruit already improved by selection, for its hieroglyphic name, BNR or BNRT, is held to be an Egyptian, not a borrowed, word; whereas, if the Egyptians had brought the palm from southern Arabia, as most students have supposed, they would be likely to have brought a Semitic name with it. The name is said to mean "sweet," and could hardly have been given to a wild representative of the species—it points rather to a good fruit, the product of centuries of cultivation.

But though the culture here, as in Babylonia, goes back at least to Neolithic times, it would be erroneous to suppose that its antiquity, in the Nile delta at least, is immense, for this alluvium was probably deposited no earlier than that of the Tigris-Euphrates, or say 10000 B. C.

The first mention of the palm in Egypt that has yet been found, according to Wilfred H. Schoff, deals not with the fruit but with wine made from the sap—the "Drink of Life" of old Babylonia—which is mentioned as an Egyptian product shipped up the Nile to Negro Land, in an inscription of the reign of Mernere in the sixth dynasty, about 2600 B. C. Thereafter the palm seems to hold front rank among the fruit trees of the country, although it does not appear frequently on the monuments until the twelfth dynasty, and at no time figures so conspicuously as in Mesopotamia. This difference, which Egyptologists have generally held to indicate a late introduction of the palm, may be explained more plausibly as showing that in Egypt the palm was merely a horticultural product: its prominence in Babylonia was not merely horticultural but, as I have pointed out, religious.

The first reference to dates as food which Mr. Schoff has found is in an Abydos inscription of Khenzer, seventeenth century B. C. In the eighteenth dynasty it springs into greater prominence, particularly in the Thebaid, but the few gardens specifically described are small: that of Anna held 170 palms, while that of a military chieftain contemporary with Amenhotep II contained 93—less

than an acre of ground, and probably therefore a mere gentleman's park, rather than a commercial plantation. Much of the Egyptian supply of dates was then secured (so H. F. Lutz tells me) from the western oases, just as it is to-day. At no time, either ancient or modern, has the cultivation of this tree attained on the Nile either the importance or the perfection that it has in Babylonia, yet it has always played a prominent part in the commerce and industry of the country. In the reign of Rameses III (twelfth century B. C.) the papyrus Harris records as "offerings for new feasts" dates, 65,480 measures, with 3,100 cut leaves—the latter for decoration; again, 241,500 measures; and as "offerings to the Nile God," dried dates, 11,871 measures, 1,396 jars; dates, 2,396 measures. It is clear that the gods, or their human assistants, had a taste for the fruit of the palm.

In Syria the palm has long been grown to a limited extent, but the climate is ill-suited to its commercial cultivation, and its early importance was rather religious than horticultural. The palm cult, probably carried northward from Babylonia, found no lack of adherents among the Phoenicians and Syrians. It is frequently to be detected among the heathen gods to whom the Old Testament prophets animadvert. None of these objects of superstition is better known, by name at least, than Baal, who was originally the god of unirrigated land as contrasted with Ishtar (Astarte), the goddess of irrigated soil and fertility. Baal is an old Semitic word which, even to-day in Arabic, means an unirrigated palm; and its metamorphosis into the execrated divinity of the idolaters is traced fascinatingly by Dr. Barton.

The cult even insinuated itself among the Chosen People. The prophetess Deborah sat under a palm, which inferentially helped her inspiration. The palm formed one of the chief motifs in the decoration of Solomon's temple—indeed, the very origin of columnar architecture is ascribed to the Babylonian use of the trunks of date-palms as building material. Thus in respect of the palm cult, as in many other respects, the religious reformers of ancient Judea were unable to keep their compatriots wholly uncontaminated by the sins of the surrounding heathen.

Phoenician traders had carried the cult to all parts of the Mediterranean as early as the Neolithic period. In graves of this age in Spain and Portugal clear evidence of it has been found. While the palm was well established in these countries before the commencement of the Christian era and may have grown there several thousand years before, its fruit was inferior, as it is to-day, and it seems unlikely that it could have become an object of veneration, save as the cult was imported by Levantine vessels coming for tin.

The same traders had established the cult in North Africa long before they founded their colonies, of which Carthage is the most famous. Two British archeologists, C. F and L. Grant, remark on this point:

Even the popularity of the Seal of Solomon pales before that of the palm, or the palm leaf, as a symbol in North Africa. It may be safely said that there is hardly any building upon which it is not somewhere to be found, in some form or other. . . . The palm appears upon nearly all the Carthaginian stelae, especially upon those dedicated to the great African god Hammon, but it has also been found upon objects dating from a civilization earlier than the Punic. M. Ohnefalsch-Richter thinks that it is a Mycenean symbol. It was certainly an ancient Libyan one before the foundation of Carthage [about 880 B C] The palm was also the great Libyan totem.

That the Greeks obtained their knowledge of the palm from the same source is evident from the name they gave it—Phoenix, the tree of the Phoenicians. As the symbol of that country it is found figured on the Phoenician and, later, the Carthaginian coins struck in Sicily. The invasion of oriental cults brought with it the use of palm leaves as symbols of victory at the great festivals—an imitation, perhaps, of their use by the Jews at their Feast of the Tabernacles, originally a feast of rejoicing at the time of the date harvest. This usage has not yet been dropped from the language: the classically-read man still agrees, *Palmam qui meruit ferat.*

Traces of the palm in Greek and Roman civilization have been diligently gathered by Victor Hehn. It is not mentioned in the Iliad, but appears in the Odyssey, particularly in the well-known scene where the far-traveled Ulysses approaches Nausicaa on the strand and flatteringly beseeches her assistance:

Never, I never viewed till this blest hour
Such finished grace! I gaze, and I adore!
Thus seems the palm, with stately honors crowned
By Phoebus' altars; thus o'erlooks the ground,
The pride of Delos. (By the Delian coast
I voyaged, leader of a warrior host;
But ah! how changed! from thence my sorrow flows;
Oh, fatal voyage, sum of all my woes!)
Raptured I stood, for earth ne'er knew to bear
A plant so stately, or a nymph so fair!

His address is quite in the oriental style, for the Beloved is told, in the so-called Song of Solomon, "This thy stature is like to a palm," a figure that can be matched in Arabic poetry at any time up to the present; while daughters of Palestinian kings bore the name Tamar, date-palm.

The palm near the temple of Phoebus in Delos, to which Ulysses refers, was one of the most famous in classical history: at its foot,

clasping the trunk with her arms, Leta was fabled to have given birth to her son Apollo. The identical tree was shown to the credulous as late as the time of Cicero and Pliny, both of whom speak of it. Much evidence has been brought together by L. Siret and others to show that Apollo was originally an oriental palm-god.

Early Italian references to the palm probably refer to the native dwarf genus, *Chamerops humilis* L., the only representative of the order that is found wild in Europe But in the early days of the city the *tunica palmata,* adopted like other badges of magisterial pomp from the Etruscans, was embroidered with leaves of the oriental palm. The legend that Rhea Silvia, mother of Romulus and Remus, saw in a dream two palms growing before the altar of Vesta, one of which shaded the whole earth and touched the sky with its crown of leaves, is evidently of late invention, imitated from the vine that, springing from the lap of Mandane, daughter of Astyages, grew till it covered all Asia; or from the olive tree seen by Xerxes in a dream, which spread over the entire earth; and these in turn perhaps borrowed from the Tree of Life in Ea's sanctuary at Eridu, which later found its way with Adam and Eve into the Garden of Eden

But as early as 291 B. C. evidence of the existence of the date-palm at Antium is to be derived from the miracle recorded concerning the snake of Aesculapius, fetched from Epidauros by the Romans during a plague. At this port the snake escaped from the ship and twined itself around a tall palm on shore. Mention by later writers suggests that the palm may frequently have appeared in southern Italy as an accompaniment of temples dedicated to Apollo; but the first knowledge of it is due to the Phoenicians, not the Greeks, if Dr. Hehn's conjecture is correct that the Roman name palma is a corruption of the Hebrew tamar.

By the beginning of the empire the date-palm is so well known that the elder Pliny is able to give an extended account of it, from Spain eastward to Persia, and to enumerate many different varieties —which seem, however, to be trade names rather than horticultural designations. The value of the fruit was not ignored, for Pliny declares, "Indeed, when in a fresh state, they are so remarkably luscious that there would be no end of eating them, were it not for fear of the dangerous consequences that would be certain to ensue."

It is not to be supposed, however, that there was any important export of this fruit from the orient to Europe, for, as W. H. Schoff has pointed out to me, freight rates would be too high to make such a commerce possible. There may have been some trade in date wine, a more valuable commodity in proportion to its weight; but this would have been as an exotic curiosity, not as a staple beverage.

The *Periplus of the Erythrean Sea* shows that there was a large export of dates from eastern Arabia to the west coast of India, about 80 A. D., and there may have been some overland exportation from Persia eastward. Dates were known in China within three or four centuries after the beginning of the Christian era, if not earlier.

Little is known of the cultivation of the palm in early Arabia, although there is some evidence of the religious cult there. Pere Anastase-Marie de St Elie, O.C., of Baghdad, has called my attention to a date-palm in Najran which was treated in all respects as a god: each year the populace celebrated the feast of this deity by attaching new clothes and jewels to the palm. The heathen divinity al-Uzza, one of the objects of Muhammad's scorn, had his residence in a grove of palms near Nakhleh—a name which itself means date-palm. But from the time of the prophet—say about 600 A D—the palm comes into the light, largely because he happened to take up his residence in a town (Medina) which was and still is the most important center of date-growing in the northwestern part of the peninsula. The zeal of the traditionists has collected, in an incidental way, much valuable information about dates Some of the legendary lore which is thus related to Muhammad is doubtless of earlier origin, and strongly suggests the influence of the venerable cult.

Fresh dates were, with melons, the prophet's favorite food, and during his period of poverty, for months at a time he had little to eat except "the two blacks," *i.e*, dates and water. It may have been partly to put the best construction on an unpleasant situation that he eulogized the palm so frequently. Of the 26 references to palms, or dates, in the Koran, 16 mention them as evidence of Allah's bounty. The others are mostly casual.

"How many a very tall palm will there be in Paradise!" he once exclaimed. Some of the generally accepted traditional lore is thus summarized by Qazwini:

> The blessed date-palm is found only in countries where Islam is the prevailing religion. The Prophet, in speaking of it, said, "Honor the palm, which is your paternal aunt"; and he gave it this name because it was made from the remains of the earth out of which Adam was created. The date-palm bears a striking resemblance to Man, in the beauty of its erect and lofty stature, its division into two distinct sexes, male and female, and the property which is peculiar to it of being fecundated by a sort of copulation. If its head is cut off, it dies. Its [male or pollen-bearing] flowers have an extraordinary spermatic odor, and are enclosed in a case similar to the sac in which the fetus is contained, among animals. If an accident happens to the marrow-like substance at its summit [*i.e.*, the terminal bud] the palm dies just as we see a man die when his skull is severely injured. Like the members of a

man, the leaves which are cut off never grow again; and the mass of fiber in which the palm is surrounded offers an analogy to the hairs which cover the human body.

In another tradition Muhammad says, "The virtuous man is like a palm: he stands erect before his Lord; in every action he follows the impulse received from above; and his whole life is devoted to the welfare of his fellow-creatures."

According to Arab historians, the germ pore on the back of the seed is due to Solomon the son of David (on both of whom be peace), who impressed it with his famous seal ring, of mingled iron and brass, inscribed with the secret name of God, by virtue of which he possessed control of all animal life and the spirit world. The medieval Christians of the orient, jealous of Muslim monopolization of the virtues of this important tree, attempted to divert some of the tradition to more worthy channels· according to their account the germ pore, which is merely a small, circular depression, is due to the fact that when Mary was eating dates under the palm, after the birth of Jesus, she exclaimed, "O, how sweet they are!" the interjection remaining indelibly printed on the seed

Association of the palm with the birth of Jesus, like that with the birth of Apollo, represents a notable and in this case a surprisingly late outcropping of the hoary palm cult. It is found in the Christian Apocrypha, and was given wider circulation by Muhammad in the Koran. Muslim commentators have embellished it, to make the most of this miracle; I quote the version of Tabari, which is an embroidery on the shorter text of the Koran:

When the time of her delivery was near at hand, Mary was ashamed to be seen by Zachariah and by the numerous temple servants, so she went out alone, leaving the temple and city behind her. Having walked some distance, she was overcome by those pains which women experience at the moment of childbirth. . . . In the distance she perceived a tree. It was a dried-up date-palm, whose leaves had fallen and whose branches had broken. Mary turned her steps toward this tree; the pains did not allow her to go any further; she sat down under that tree, as it is said in the Koran: "The pains of childbirth came upon her near the trunk of a palm." When her delivery was completed, and she had brought Jesus into the world, the pains and shame caused her to utter these words: "Would to God that I had died before this, and become a thing forgotten." The Koran continues: "A voice below her cried out, 'Be not grieved; now hath God provided a rivulet under thee' ". When Jesus first saw the light of day under this palm trunk, there was in that locality no rivulet, nor water of any kind. God caused a spring to gush forth from that place, and the water flowed along the ground, in order that with this water Mary might bathe herself and Jesus. Then the voice said to her: "Do thou shake the trunk of the palm, and it shall let fall ripe dates upon thee." Mary shook the tree, and at that instant dates appeared, ripened and dropped. She ate some of them, and her body regained

its strength. The date is a hot fruit; when it is given to a woman weakened by childbirth, it restores her strength. This is the reason why a woman newly delivered of a child is given dates or a cake made from dates. From God himself was this usage learnt.

An early tradition put the birth in Egypt, near the town of Ahnas: Kaab al-Ahbar declares he saw the identical palm there, and Makrizi bears witness to the same effect, while Ibn Haukal, in describing the town of Akhmim, Egypt, relates, "It is said that the date-palm, of whose fruit Mary ate, has been placed in the dome or vault which is here, and is held in high respect." Ibn Batutah, one of the most sober-minded of Muslim travelers, avers that he saw "traces" of it in the church at Bethlehem.

Because of this legend, Muslims sometimes refer to Jesus by the name of Dhu al-Nakhleh, "the date-palm man."

With the transfer of the caliphate to Baghdad in 750 A D , literary emphasis of the palm again shifts to the place of its origin, but the mists of mythology begin to clear away. The paternal aunt slowly ceases to be a goddess, and remains merely a very useful and much respected member of the family.

A DESERT TRAGEDY

A DESERT TRAGEDY

By Dr. DAVID STARR JORDAN

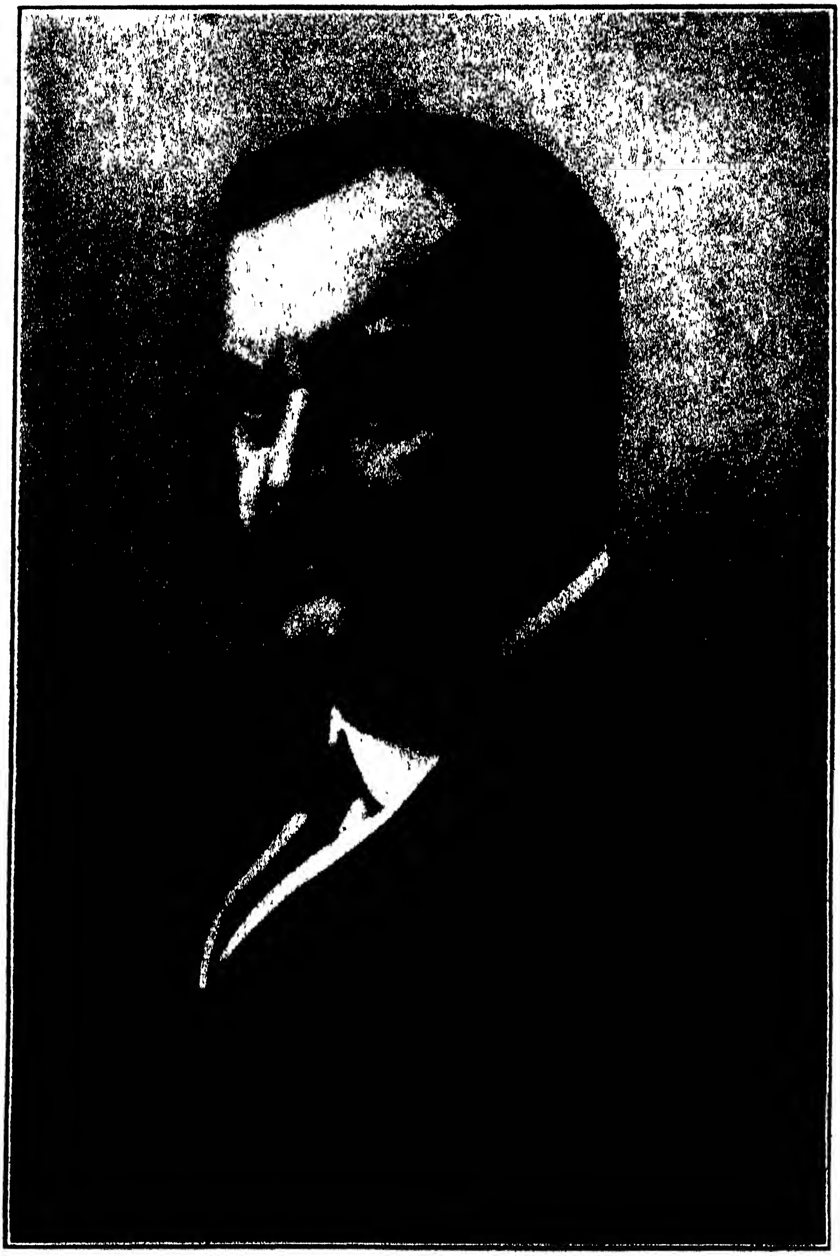
STANFORD UNIVERSITY

In the little drama I shall set forth the actors are two: First, a desert bob-cat, *Lynx eremicus*; and, second, a great horned owl, *Bubo virginianus*. The scene is laid on a cliff in the desert in the western part of Fresno County, California; the hour, towards sunset, in the summer of 1901.

The wildcat is watching for jack rabbits from the top of the cliff, his colors, gray and rusty, matching the color of the rocks. The same colors are borne by the jack rabbit, the prey of the owl, and this animal the great owl unwittingly takes him to be. She swoops down on him with her great beak and long sharp claws. Both are surprised, and each is a match for the other. The wildcat has by far the stronger jaws, the bird has the advantage in his claws, and in the wings which should afford means of escape if the attack went wrong.

Whatever the theoretical handicap on either side, the two were equal in fact. The cat seized the bird's great wing at the wrist joint, crunching the bones and rendering the wing useless. The owl thrust its long, sharp claws through the muscle of the cat's fore-leg rendering the cat helpless to move. There was no help to either side, "no referee to call a foul." So they struggled through the night, at last falling from the cliff stunned and dying. There they lay, locked in fatal embrace for a month or two, their flesh drying in the desert sun

At last Mr. Edwin R. Graham, a prospector from Hanford, found them there, and sent them up to Stanford University. There a photograph of the pair was taken by Charles F. Lummis, of Los Angeles, through whose courtesy it is reproduced here. The story of a "Duel in the Desert" was published by him in his inimitable journal, *Out West*, in January, 1902.



MAJOR-GENERAL SIR DAVID BRUCE

President of the British Association for the Advancement of Science which met in Toronto from August 6 to 14. Sir David Bruce's presidential address was on the prevention of disease, to which subject he has made distinguished contributions.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

VITAMINS

THE vitamins, infinitesimal but indispensable ingredients found in our food, formed the topic of one of the most exciting sessions of the British Association for the Advancement of Science at its Toronto meeting. "Found in our food" is the wrong phrasing, for the vitamins are in our food but not yet found, although the chemists of all countries are hunting for them as hard as they can. But it is hard to find something when you can not see it and do not know what to look for. A blind man could easier find a needle in a haystack, yet the search seems to be nearing success. Professor Walter A. Eddy, of Teachers College, Columbia University, was able to exhibit a small sample of what appears to be a vitamin in a form sufficiently pure to be crystallized and analyzed. The analysis indicates that its molecule is composed of five atoms of carbon, eleven of hydrogen, three of oxygen and one of nitrogen. The process of extraction is a tedious and delicate one. Starting with six pounds of fresh yeast, he thinks himself lucky in being able to get out seventy milligrams of the product in the end. But this is so potent that five hundredths of one milligram per day added to the ration of a young rat on a deficient diet will restore it to health and start it growing. The same substance has a stimulating effect on the growth of the yeast plant. Such a yeast promoter is known as "bios," but whether his product is a known vitamin, or whether it is essential to the growth of mammals or even to all kinds of yeast, are questions on which Professor Eddy is not yet ready to commit himself.

Professor Lash Miller, of the University of Toronto, who has been working for many years on bios, has separated it into two different fractions. These are present in varying proportions in many vegetables, and he has found tea the most convenient source for its preparation in quantity. Both kinds of bios have to be present to produce the full effect in the rapid multiplication of yeast cells.

The vitamins may turn out to be the clue, not only to the cause of many obscure diseases, but also to some of the problems of history. What is called race suicide or class suicide may be due in part to an accidental dietary deficiency for Professor Herbert M. Evans, of the University of California, showed that besides the vitamins necessary for health and growth there is another that he provisionally calls "Vitamin X," which is essential for reproduction. Rats living on food devoid of X will grow up and thrive and live apparently normal lives, but the male can not generate, and the females can not bring forth young. Fertility can generally be restored by adding to the ration some food containing the lacking vitamin or a few drops of the concentrated extract. Wheat germs, lettuce, egg yolk, liver, vegetable oils, and butter, especially butter from alfalfa-fed cows, are among the foods containing Vitamin X, but it is absent from skimmed milk, sugar, white bread and cod-liver oil, although cod-liver oil

is very rich in the vitamins that promote growth and prevent rickets. A mother may transmit a limited supply of X to her offspring, but not enough to last through life. Sterile rats may be cured by feeding on the flesh of normal rats. Professor Evans finds he has been able to extract X from wheat germ in quantity and to obtain it as an oil of high potency, but has not yet obtained it pure enough to determine its chemical composition. That a shortage of the fat-soluble Vitamin A may increase the liability to lung trouble was shown by the experiments reported by Professor H. C. Sherman, of Columbia University. Rats which had an insufficient supply of this vitamin in an otherwise adequate diet "showed a striking tendency to break down with lung disease at an age corresponding to that at which pulmonary tuberculosis so often develops in young men and women. The bacillus involved is different, but the close parallelism in susceptibility of lung tissue to infection at this stage of the life history appears very significant, especially in view of the further observation that the fat-soluble vitamin content of the lung tissue varies with that of the food." Of two similar sets of rats, kept on identical diet, except that one was deficient in fat-soluble A, the females on the complete ration bore an average of twenty-eight young and reared sixteen each, while those on the diet low in this vitamin bore an average of two young and reared none whatever, and lived only half as long. Both batches had Evans's Vitamin X, so evidently Vitamin A is also necessary for reproduction.

Butter is rich in Vitamin A and cod-liver oil richest of all, so the practice of prescribing these fats in case of consumption is substantiated by recent researches. Carrots are much richer in this vitamin than potatoes or turnips, spinach is richer than lettuce, and green celery than the bleached leaves.

CUBICAL CULTIVATION

THE city man has the advantage of the countryman in that he can expand his business perpendicularly. Our city "squares" have become cubes, but the farmer lives in Flatland like all his ancestors. When he buys an acre of land, he only gets an acre area. But when the city man buys an acre, he piles story on story till he gets ten or twenty acres of floor space out of it. The forester, it is true, can raise his foliage factory to the height of a house, but then the shaded space beneath becomes useless.

But in part of the world these limitations on life do not apply, and this is the greater part of the earth's surface; in fact, seventy-one per cent. of it. For water, unlike soil, is transparent, and the sunlight, which supplies the vital energy to all vegetation, can penetrate the ocean to the depth of a thousand feet or more, which beats the sky-scraper by far. Think of having a garden measuring five hundred feet by five hundred by five hundred feet full of growing vegetation! And what a pasture that would make for stock able to feed off every cubic foot of it!

Such garden plots and such pastures there are in the sea, but so far man has done nothing in the way of cultivating them. His control stops with the shore. The modern man merely hunts in the ocean as his ancestors did in the forest, unsystematically, wastefully, often disastrously, destroying what he desires.

Man has hardly yet begun to consider the conservation of the wild life of the sea, still less its cultivation. These are questions for the future.

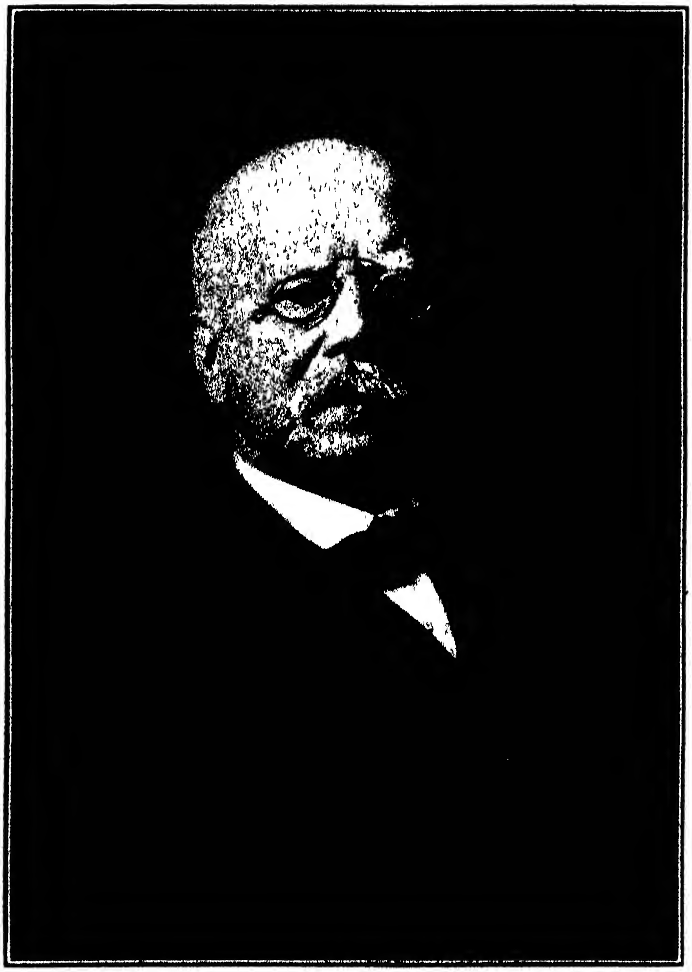
But this future is rapidly coming, for each year the fishing craft have to go farther and farther out to sea and use more power in getting their haul. British trawlers can now get only about half their fish from the North Sea, and they are forced to trawl the banks of the Faroe Islands and Iceland. It takes eight to ten tons of coal to catch a ton of fish and the trawler gets on the average only about five cents a pound for it at the port. Before the war a British steam trawler of 125 feet in length could be run profitably for less than $20,000 a year. To-day it costs some $50,000. Coal and nets are twice the pre-war price.

The herring fishing of Great Britain has been hardest hit by the war. In 1914 the industry was worth nearly $25,000,000 a year and employed some 60,000 people. More than 2,250,000 barrels of pickled herring were exported. But seventy per cent. of these exports went to Russia and twenty per cent to the Germans, and now the Russians have locked their doors and the Germans have scant money to pay. Poland and the United States have curtailed the market by putting duties on imported herring. Consequently, British fishers are asking government aid and protection against foreign fish, a sad situation for an industry that has maintained its proud independence and supremacy for five hundred years.

In 1424 the herring migrated in mass from the Baltic to the North Sea for some mysterious reason, and this sudden shift of the shoals built up the British seapower and made Germany and Russia dependent upon British fishermen. We may hope that eventually the financial embarrassments and the present impediments to commerce may be removed or readjusted, but until we learn more about ocean life we shall not be able to make full use of the harvests of the sea. We have taken the first step when we realize that there is a "reason" for such a migration, even though we must admit that it remains "mysterious." If we open the stomach of a herring, we may find it contains as many as 60,000 copepods. The copepods are primitive crustaceans that look like tiny shrimps. They feed on the minute plant forms found in the thick sea-soup, called "plankton," that is scooped up in a tow net. There are 2,500 diatoms to one copepod. Now the diatoms are extremely sensitive to changes in the composition of the sea water, its alkalinity and the percentage of salt and lime it contains. And, of course, the growth of all such vegetation depends upon the amount of sunshine that falls upon the sea and the depth to which it penetrates. The diatoms swarm when the temperature gets right With them come the copepods that browse upon them. The fish eat the copepods and we eat the fish. So our Friday dinners depend upon the diatoms and national prosperity may be determined by the plankton.

Herring on the Atlantic side of Ireland and of Nova Scotia are larger than in the interior waters on the other side. The warmer the water, the saltier the sea, and the greater the amount of oxygen in the water the faster grow the fish. But the oxygen in the water increases with the atmospheric pressure, so the growth of the young herring varies with the barometer.

That is why the biologists of the marine research stations of Wood's Hole on the Atlantic, and La Jolla on the Pacific are continually analyzing the sea water, taking the temperature of the ocean and patiently counting the copepods and diatoms with the microscope.



THOMAS CORWIN MENDENHALL

By whose death, at the age of eighty-two years, America loses a distinguished physicist. Dr. Mendenhall was formerly professor at the Ohio State University and at the University of Tokio, president of the Rose Polytechnic Institute and of the Worcester Polytechnic Institute, superintendent of the Coast and Geodetic Survey and at the time of his death president of the board of trustees of the Ohio State University.

HOT WEATHER CLOTHING

In these days when we are largely occupied in efforts to keep cool, it is worth while to spend a little thought on the fundamental principles of heat movement and how we can apply them to the problem.

In the first place we must remember that our object is not so much to keep the heat out as it is to get the heat out. Our internal stoves, where food serves as fuel, produce heat enough to raise us to the fever point in a few hours and to cause death by what is commonly called "sunstroke," even though there were no sun, if we could not continually pass off our surplus heat to the surrounding air.

The air will consent to relieve us of our surplus heat on two conditions: first, when the air is cooler than our bodies, and, second, when it has less water than it can hold. If the air is above 99 degrees Fahrenheit and has 100 per cent. humidity, there is no help for us.

Fortunately the air roundabout rarely attains these two conditions, but the air that is kept in contact with the skin as by tight or thick clothing does get to the same temperature as the body and does take up all the moisture it can hold. In that case the only thing to do is to get rid of this old air and get in some new that is capable of absorbing heat and perspiration.

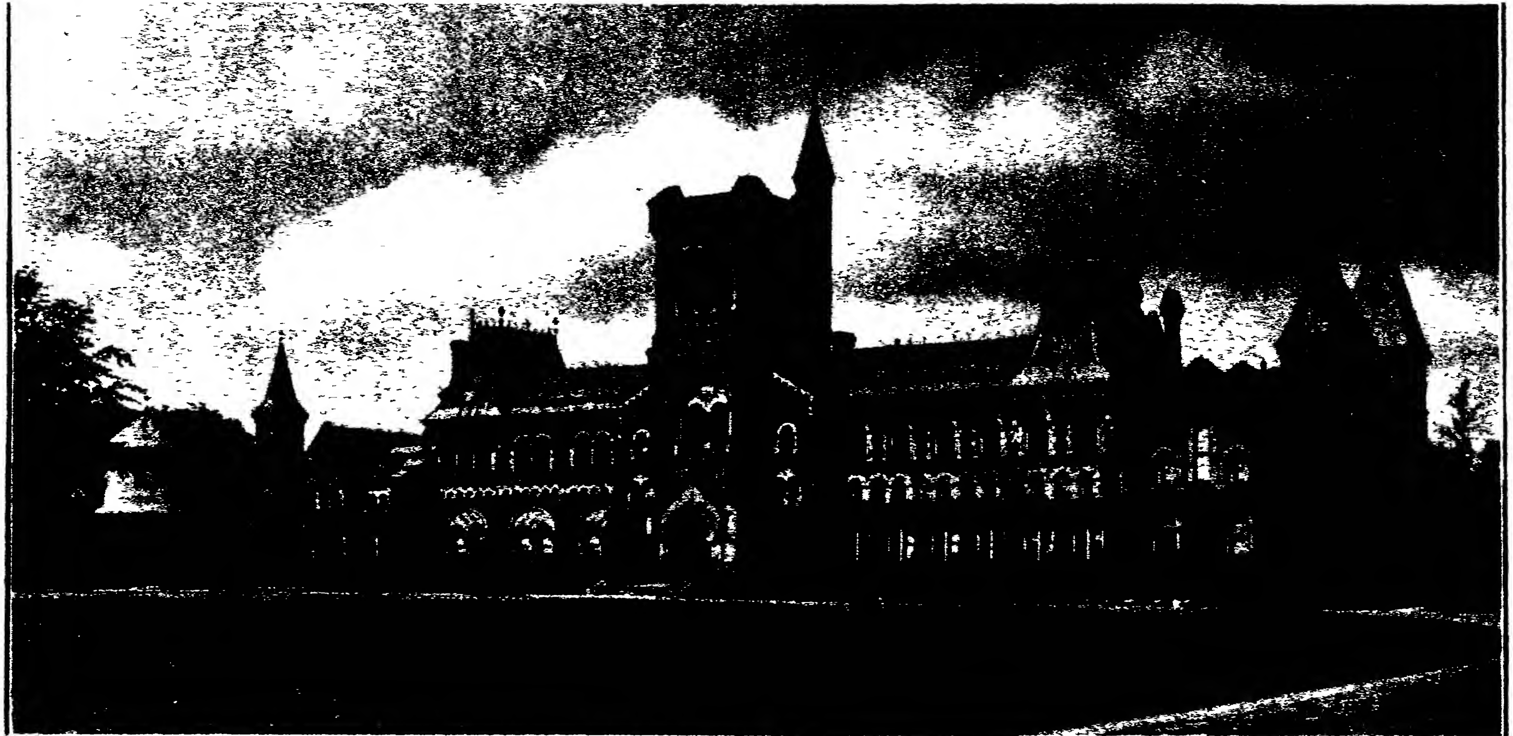
From a purely theoretical point of view, therefore, the ideal midsummer costume would be to wear a large umbrella and nothing else. But to apply a scientific theory without regard to local circumstances is often unwise and sometimes unsafe. Yet whatever deviation from the ideal local custom may require, we should bear in mind the fundamental principle that cooling is due chiefly to evaporation and that evaporation depends upon ventilation. Close clothing keeps a hot and humid layer of air in contact with the skin so that we who rejoice that we dwell in the temperate zone are really living the year around in a tropic atmosphere except for our hands and face. The circulation of air should theoretically be sufficient to keep the skin free from uncomfortable accumulation of perspiration, but not so rapid as to chill it by excessive evaporation. It is not the sweat we see that cools us, but that which passes off unperceived. To evaporate the water from a man's wet clothing may require as many calories as he gets in a day's food.

Clothing halves the loss of heat in cold weather and cuts it down still more in warm weather. The clothed man ranks between the furry dog and the rabbit in the matter of heat exchange.

If our skin were a sheet of silver foil of the same thickness, we should lose heat 2,280 times as fast as we do, but a layer of immobile air, such as may be caught by fur, feathers or close-knit cloth, will retard the loss of heat ten times as much as the skin.

To keep the air in free circulation over the skin, the clothing should touch the skin as little and as lightly as possible. Coarse-meshed and porous fabrics are better than fine cloth.

The weave makes more difference than the color. It is true that black clothing absorbs about twice as much sunlight as white, but that does not tell the whole story, for it is heat that we want to keep out, and more than half of the sun's heat is not seen by the eye as light. We see about an octave of the solar spectrum, from the red waves of lowest frequency to the violet of highest frequency. But beyond the violet there are two



UNIVERSITY COLLEGE, UNIVERSITY OF TORONTO,

Where the British Association for the Advancement of Science and the International Mathematical Congress met in August.

octaves and below the red there are six octaves that we can not perceive with the eye. At high noon in the latitude of Washington, fifty-one per cent. of the energy of solar radiation comes in the form of the dark heat rays of the infra-red, forty per cent. as visible light, and nine per cent. as ultra-violet rays, also invisible but the most powerful of all in their effect on the skin. It is the ultra-violet rays that are responsible for tanning and burning. Now the dark heat rays pass equally well through dark and light cloth, and the ultra-violet chemical rays pass better through light than dark.

Leonard Hill, the great English authority on climatology, commends the Egyptian robes as the most comfortable garments for a hot country for "as the native walks his garments sway and flap in ungainly fashion, but in doing so cause air currents, which have a cooling effect." The missionaries' wives, when called upon to devise a costume for the women of the Pacific Islands, did well from a sanitary point of view when they clothed them in "Mother Hubbards," though they could hardly have done worse from an artistic point of view.

But it is not necessary for clothing to be unbecoming in order to be comfortable. Probably American women have never been more seasonably clad than they are this summer, but no one could call their costumes ungainly. The men, too, although they are more conservative and less original than women in matters of dress, have made some progress of late in the adaptation of their clothing to the summer season, but their tight collars and belts are contrary to the first principles of hot weather costume.

DREAMS TO ORDER

THE interpretation of dreams has been an object of eager interest for more than three thousand years. The latest journals of psycho-analysis deal with the same question as the earliest papyri of Egypt or cuneiform bricks of Assyria—and with little more success.

Isn't it time then that we attacked the problem from the other side? Instead of wasting so much time endeavoring to determine what dreams mean, would we not make better progress if we tried to find out what makes dreams? Then we could get whatever dreams we liked and whenever we liked and need not bother about their interpretation

We now have some prospect of progress in this direction, for our new knowledge of the hormones gives us a clue. A case in point is reported by Finley. He had a woman patient to whom he gave a grain a day of extract of the pituitary body to build up her blood pressure. Her dreams had hitherto been trivial and colorless, but after ten days of the treatment she began to have pleasurable and highly colored dreams. She traveled extensively in her dreams, as she had always longed to in reality, and wherever she went she found the stations and cars freshly painted in pleasing colors and the trainmen in nice new uniforms with gold braid.

Shortly after the treatment was altered and adrenalin, another of the glandular secretions, was substituted. At once a change came over the spirit of her dreams. They lost their colors and became horrible, filled with violent quarrels.

Now if a Freudian practitioner had taken the case, he would have proceeded to probe for complexes in her unconscious without even putting her under an anesthetic. He would diagnose the former dreams as due

to "suppressed desires," instead of pituitrin, and the latter as due to "infantile fears," instead of adrenalin. Yet the doctor could produce either brand of dreams at will by an infinitesimal dose of white powder.

Fear and rage promote the secretion of adrenalin from the suprarenal glands. Conversely, the injection of adrenalin, which may be made in the laboratory, will stimulate the symptoms of fear, the goose-pimples, the hair-raising, the cold-sweat, and all that. And James showed years ago that with the symptoms come the corresponding emotion.

It seems from this case that dreams may be made to order like picture postcards, one cent plain and five cents colored Common dreams come plain in black and white and grey, chiefly grey. Most of us are colorblind for a third of our lives. My dreams are usually fragmentary and fugitive, shadowy and colorless. But once when I took laudanum there was unveiled before me a series of the most wonderful pictures, minute and sharp as the landscape seen through the big end of an opera-glass, and as brilliantly colored as a Chinese rice-paper sketch. It was an unprecedented experience for me, and I realized for the first time what delights are enjoyed by the favored few who have colored dreams naturally.

De Quincey in his "Confessions" and Baudelaire in his "Hymn to Opium" depict in the most glowing terms that English and French afford the delights of the opium dream. But those who seek an artificial paradise by way of the alkaloids find ultimately that they have jumped out of ennui into anguish. De Quincey soon found himself chased by Chinese, kissed by cancerous crocodiles, and suffering other forms of alliterative torment.

Opium and hashish in the Orient, alcohol and cocain in the Occident, have been from time immemorial the favorite means of escaping from this dull world into the dreamland of Euphoria. Hashish also intensifies color perception and excites chromatic dreams. I knew a lady who was accustomed to take a pinhead pill of hashish gum before going to the theater because it brightened the scene and converted the painted back-drop into a spacious landscape.

The internally secreted hormones are similar in potency and effect to the externally administered alkaloids. An overdose of insulin, a hormone secreted by the pancreas, causes feelings of "causeless" fear, followed by trembling and finally collapse. The patient can recover his courage by sucking a stick of candy. An excess of activity on the part of the thyroid gland excites anxiety and irritability.

Possibly anxiety and terror dreams in general may be caused by some disturbance in the balance of the hormones or similar organic derangement rather than by anything peculiarly unpleasant in one's past experiences or present predicament.

Certain foods are reputed to produce bad dreams, but this is uncertain. I have often been warned against eating mince pie or Welsh rabbit before bed time, but when I tried the experiment I saw neither hair nor hoof of a nightmare. Nobody ever told me of any foods that would give pleasant dreams. I wonder why. Aren't there any? But some day the chemist may give us synthetic dreams by his synthetic compounds and then shall our sleep always be happy and the nightmare shall be no more.

৹THE SCIENTIFIC MONTHLY

OCTOBER, 1924

RENSSELAER POLYTECHNIC INSTITUTE AND THE BEGINNINGS OF SCIENCE IN THE UNITED STATES

By Professor RAY PALMER BAKER

RENSSELAER POLYTECHNIC INSTITUTE

DURING the first week in October, Rensselaer Polytechnic Institute celebrates the hundredth anniversary of its foundation Since the school founded at Troy in 1824 by Stephen Van Rensselaer is the oldest institution devoted to science in any English-speaking country, and since its early courses related to both the farm and the factory, it was a pioneer in many fields; and it affected materially the development of many institutions.

In order to understand its influence during the first four decades of its history—a period in which a majority of the scientists in the republic were numbered among its graduates—it is necessary to know something at least concerning the man selected as its academic head. Amos Eaton was an original genius of profound and far-reaching intellect. Educated at Williams, the first of its alumni to achieve distinction, he studied at Yale under Benjamin Silliman, who lived to see his pupil transcend the barriers which had inhibited his labors in New Haven Returning to Williamstown in 1817, he conducted a series of extracollegiate lectures on botany, geology and mineralogy which were attended by all the seniors and juniors and by all but four of the sophomores and freshmen. So popular were these lectures that the undergraduates of their own volition published the manuscript of the first group. Because of this success, Eaton determined to offer experimental courses wherever he could find an audience. As a result, over seven thousand students—in his day, an unprecedented number—attended his classes in natural history. In addition to those treated in this sketch, many of the most eminent scientists of the day—leaders like James Dwight Dana, professor of natural history in Yale University, Chester Dewey,

AMOS EATON
Amos Eaton (1776–1842) Senior Professor and Professor of Chemistry and Experimental Philosophy in Rensselaer Polytechnic Institute.

professor of chemistry in Rochester University, Asa Gray, professor of natural history in Harvard University, Albert Hopkins, professor of astronomy in Williams College, and John Torrey, professor of chemistry in Columbia University—began their work under his direction.

Now that it is possible to view his achievements in true perspective, it is clear that he is one of the great figures in the history of science in the United States. Though his botanical nomenclature has often been modified, the value of his researches has become increasingly apparent; and recent investigations by the United States Geological Survey have strengthened his position as the "father of American geology." Nevertheless, striking as were his discoveries and monographs, they were surpassed by his services to the cause of education. The first to introduce field work and laboratory practice into the American college, the founder, in Troy, of the first popular museum of natural history, a pathfinder in many fields, he illumi-

nated by his personality the city which he made his home. Devoted to the practical affairs of life, he still worshipped truth for its own sake; and it was this rare union of intellectual curiosity and rough-and-ready utilitarianism which made Rensselaer a center of "pure" scholarship—a development with which I am going to deal—as well as a school of agriculture and, after 1835, a college of technology.

Since he was a naturalist of the Old School, almost a "philosopher," in the Chaucerian sense, he ranged over many subjects—botany, zoology, physics, chemistry, geology and mineralogy; and in every field he fired the imagination of students who outreached him in knowledge and attainment. This statement is true of several of the biological sciences which to-day seem remote from the curricula of the institute. By 1828, Eaton had published treatises, manuals, exercises and dictionaries dealing with various aspects of botany The eighth edition of his "North American Botany," issued in 1820, contains descriptions of 5,267 species Under the circumstances, it is not surprising that many of the early graduates followed in his steps. Some of them paralleled his intellectual excursions with remarkable fidelity. James Hall ('32), of whose work at the University of Iowa I shall speak later, printed his "Catalogue of Plants Growing without Cultivation in the Vicinity of Troy, N Y " in 1832, before he began his career as a geologist. Douglas Houghton ('29), who organized the Michigan State Geological Survey after the commonwealth had been admitted to the Union, acted as botanist on the first expedition to the source of the Mississippi His able report on the flora of the Northwest can be traced to-day in the Houghton Herbarium at the University of Michigan. When he undertook the survey in 1837, he naturally surrounded himself with Rensselaer men, one of whom, Abram Sager ('31), now remembered by the Sager Herbarium, became chief of the botanical and zoological divisions. Sager, who, like several other graduates of the institute before 1850, luxuriated in every field from paleontology to obstetrics, laid the foundations of the departments of botany and zoology in the university. It is true that Asa Gray, who had also been inspired by Eaton, had been connected with it for a few months, but his connection was merely nominal. As in several of the other universities in the west, the pathfinders had been students in Troy.

Moreover, through his lectures, delivered at Amherst, Northampton and elsewhere, Eaton influenced a number of women who were to become conspicuous in the first half of the nineteenth century. "You can generally," he remarked, "persuade ladies to go out in small parties to the nearest open fields" and collect plants for the next day's study. And many evidently did go; for, in 1819,

Jane Welsh, who had been a member of his classes in Northampton —where he conducted the first courses in science ever opened to women—issued her "Botanical Catechism." Ten years afterward Almira Lincoln, a sister of Emma Willard, published her "Familiar Studies in Botany," a volume based upon Eaton's manuscripts. Finally, in 1840, Laura Johnson, who, like Mary Lyon, founder of Mount Holyoke College, had been a guest at his home and a student under him, put forth, under his supervision, the second edition of her "Botanical Teacher," a companion to the eighth edition of Eaton's "North American Botany." So far as I am aware, the movement culminating in this literature—a movement designed to "promote knowledge and magnify the Creator"—was the first of its kind on the continent.

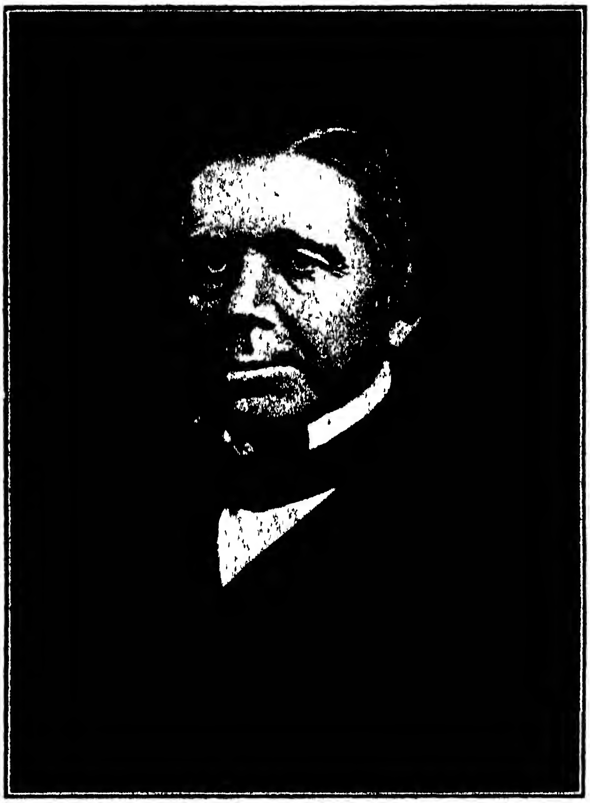
Though Eaton's "Zoological Syllabus and Note Book," published in 1822, emphasizes his interest in the biological sciences, the character of this interest is revealed more accurately by his "Geological and Agricultural Survey of the County of Albany, N. Y." (1820) and his "Geological and Agricultural Survey of the District Adjoining the Erie Canal" (1824) These volumes, reports of investigations which he had made through the patronage of Stephen Van Rensselaer, illustrate the practical side of his genius They are interesting memorials of the first attempts to adapt the results of research to the needs of agriculture. When the history of education in the United States is finally written, it will be found, I think, that the institute was a powerful factor in shaping the agents which have ministered to its necessities.

In 1843, Ebenezer Emmons ('26), who lectured—as usual at the time—on geology, mineralogy and chemistry, in Albany, Rensselaer and Williams, and who, in 1836, became head of one of the four divisions of the New York State Geological Survey, was appointed chief of the agricultural section. In the next decade he issued four reports, the first dealing with the soils and rocks of the district, the second, with the grains and vegetables; the third, with the fruits; and the fourth, with the noxious organisms. From his monographs, which were illustrated—for the first time—by figures and plates, have sprung the bulletins of the United States Department of Agriculture Even in the case of the bureaus associated with it, the institute was also a leader. In 1830, Eaton organized the first of his famous "expeditions" for the collection of plants, insects, rocks and fossils On this excursion from New York to Lake Erie—an excursion which marked the beginning of serious field work in America—he was accompanied not only by Houghton, Emmons and Fay Edgerton ('28), whom I shall mention again, but also by Asa Fitch, Jr. ('27), who specialized in entomology.

EBENEZER EMMONS, '26

Ebenezer Emmons (1796–1863) Junior Professor in Rensselaer Polytechnic Institute. State Geologist of New York for the Second District. Professor of Geology and Mineralogy in Williams College. Chief of the Agricultural Department of the New York State Geological Survey. State Geologist of North Carolina.

Henceforth Fitch devoted himself to this study. In 1848, he was engaged by the New York State Agricultural Society to make a survey of Washington County, the results being incorporated in the *Transactions* of 1848–49. Previous to this time, however, he had contributed numerous articles to the *American Quarterly Journal of Agriculture and Science,* which had been projected by Emmons Among the subjects which he treated were the wheat midge, the Hessian fly and the currant worm. At last, in 1851, after he had collected and classified a large number of specimens for the State Museum, he prepared a catalogue of homoptera which is still valued by specialists. In view of his reputation, it was natural that when the legislature in 1854 appropriated funds for the employment of an official entomologist—the first in America—he should have been selected for the position. During the next thirteen years, a period in which he issued a series of annual reports, he made secure his



ASA FITCH, JR., '27
Asa Fitch, Jr. (1809–1878). State Entomologist of New York.

place as the "father of economic entomology." Although Van Rensselaer's aspirations regarding agriculture were soon obscured by the claims of industry, they have thus been realized in the activities of the national bureaus which are the legitimate descendants of the small organizations established by Emmons and Fitch.

The part played by the graduates of the institute in the first colleges of agriculture was no less important. West of the Alleghany Mountains, they found people peculiarly responsive to the theories of education which they had brought from Troy. The Morrill Act of 1852, foreshadowing the type of institution which Eaton had envisaged, offered them an opportunity of which they took full advantage. When the University of California was opened in 1869, Ezra Slocum Carr ('38), who had held the chair of chemistry and natural history and of chemistry as applied to agriculture in the University of Wisconsin, was called upon to become first professor of chemistry as applied to agriculture, or, as

EZRA SLOCUM CARR, '38

Ezra Slocum Carr (1819–1894). Professor of Natural Science in Middlebury College. Professor of Chemistry and of Natural History in the University of Wisconsin State Superintendent of Education in California.

he was more often called, merely "professor of agriculture." The career of Hall, however, offers an even better illustration of the ideas which Rensselaer men carried beyond the Mississippi. In connection with the Iowa State Geological Survey, he became first professor and head of the department of natural history in the university, which he helped to establish. Though he apparently never delivered any lectures, he insisted not only on the importance of botany, zoology, geology and mineralogy from an academic point of view but also upon the necessity of considering their applications to agriculture. According to President MacBride, he anticipated the progress of the commonwealth in rural education. In similar paths the alumni were also trail-breakers; for George Hamill Cook ('39)—like Hall, an adventurer in many fields and professor of geology and agriculture in Rutgers College—became director of the first experiment station in New Jersey, one of the earliest on the continent. In the bureaus, colleges and laboratories devoted to

GEORGE HAMILL COOK, '39

George Hamill Cook (1818–1889) Senior Professor and Professor of Chemistry, Mineralogy and Zoology in Rensselaer Polytechnic Institute. Professor of Chemistry and Natural History in Rutgers College. State Geologist of New Jersey. Director of the New Jersey Agricultural Experiment Station.

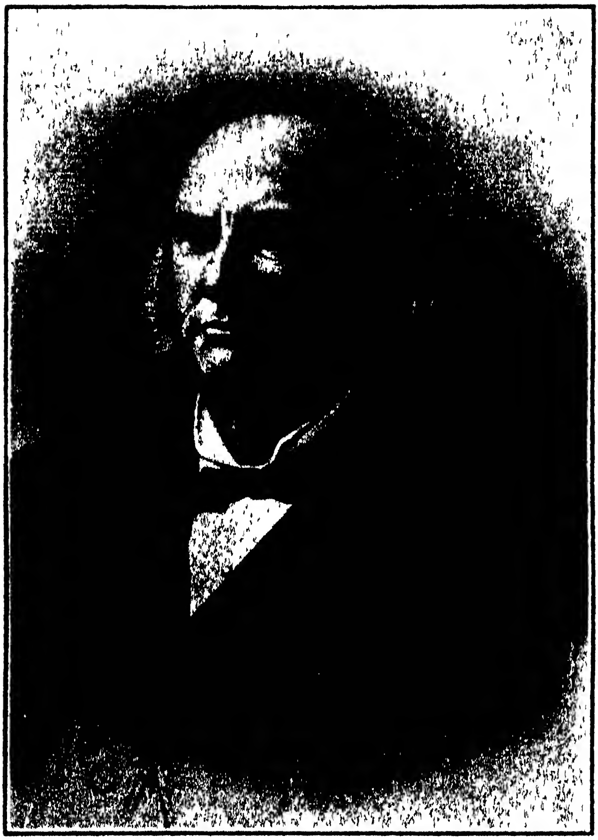
agriculture the ideals of 1824 still linger, although the students of the institute no longer "amuse" themselves on pleasant afternoons by studying vegetables or pruning trees on "well-cultivated farms" in the neighborhood.

The interrelation of the natural sciences before 1875 is especially noticeable in the case of those which belong to the second group. In the early part of the nineteenth century, "natural science" and "experimental philosophy" went hand in hand. It is difficult to divorce them. In fact, three graduates of the institute, the most distinguished of whom was John Pemberton, Jr. ('60), held professorial posts under this double-headed title at the United States Naval Academy. By 1850, however, physics was able to stand alone. Since most of the alumni, however, were teachers and not investigators, they have left little trace of their labors, except in the institutions which they served, although George Washington

HENRY AUGUSTUS ROWLAND, '70

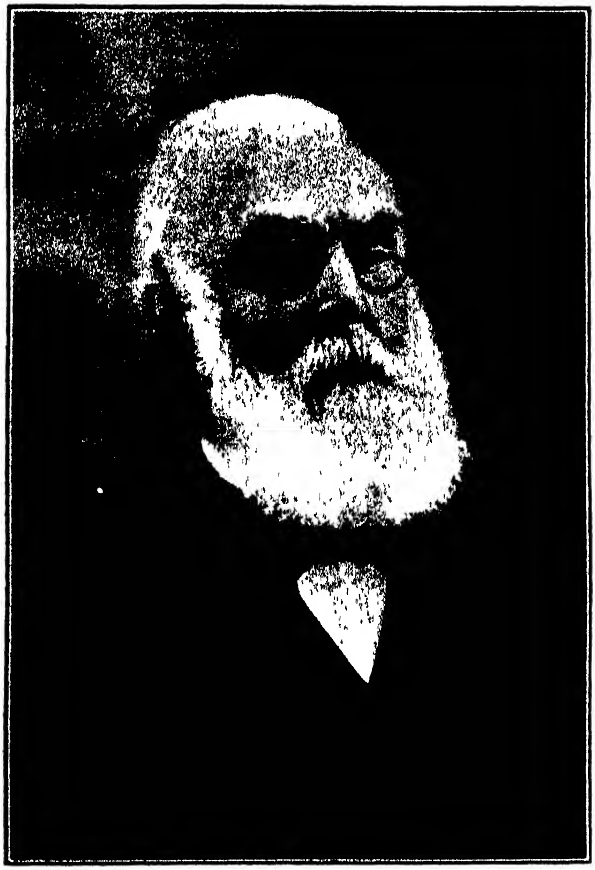
Henry Augustus Rowland (1848–1901). Head of the Department of Physics in Rensselaer Polytechnic Institute. Professor of Physics in Johns Hopkins University.

Plympton ('47) must be credited with many advances at both the Brooklyn Polytechnic Institute and the Cooper Institute. In Michigan, also, De Volson Wood ('57), who, with President Tappan, had been requested by the Board of Regents to formulate a policy to govern the teaching of the sciences, inaugurated the system of independent colleges for the pure and applied sciences which has been adopted by most, or all, of the state universities. The one alumnus, however, who left a permanent impress upon his generation was Henry Augustus Rowland ('70). Since his father, grandfather and great-grandfather had been clergymen, graduates of Yale, he was naturally sent to Newark and Andover to prepare for college. So great was his dislike of Latin and Greek, however, and so absolute was his devotion to mathematics and mechanics, that he was eventually allowed to enter Rensselaer, where, in spite of the meagerness of its equipment, he immediately felt at home. Except for a couple of terms at Yale, he spent the next five



EBEN NORTON HORSFORD, '38
Eben Norton Horsford (1818-1893). Rumford Professor of Chemistry in Harvard University. President of the Rumford Chemical Works.

years in Troy. Graduated as a civil engineer, he passed a year in the field and another as instructor at Wooster, Ohio. In 1872 he returned to the institute. During the next three years, in which his salary as assistant professor of physics was decreased—for such was the agreement—as the appropriations for apparatus were increased—he began the investigation of magnetic permeability which established his reputation in Europe. As a result, he was appointed first professor of physics in Johns Hopkins University; and, in 1876, after a trip across the Atlantic to purchase supplies, he set up his "shop" in the two houses which he was to make famous. Born at a fortunate moment and called to a chair carrying with it opportunities for research unrivalled in America, he influenced the study and teaching of physics in a manner which is not likely to be paralleled in the future.



JAMES HALL, '32

James Hall (1811-1898). Professor of Chemistry and Physiology in Rensselaer Polytechnic Institute State Geologist of New York for the Fourth District. State Geologist and Paleontologist of New York. State Geologist of Iowa. Professor of Natural History in the University of Iowa. State Geologist of Wisconsin. Professor of Theoretical, Practical and Mining Geology in Rensselaer Polytechnic Institute. Director of the New York State Museum of Natural History.

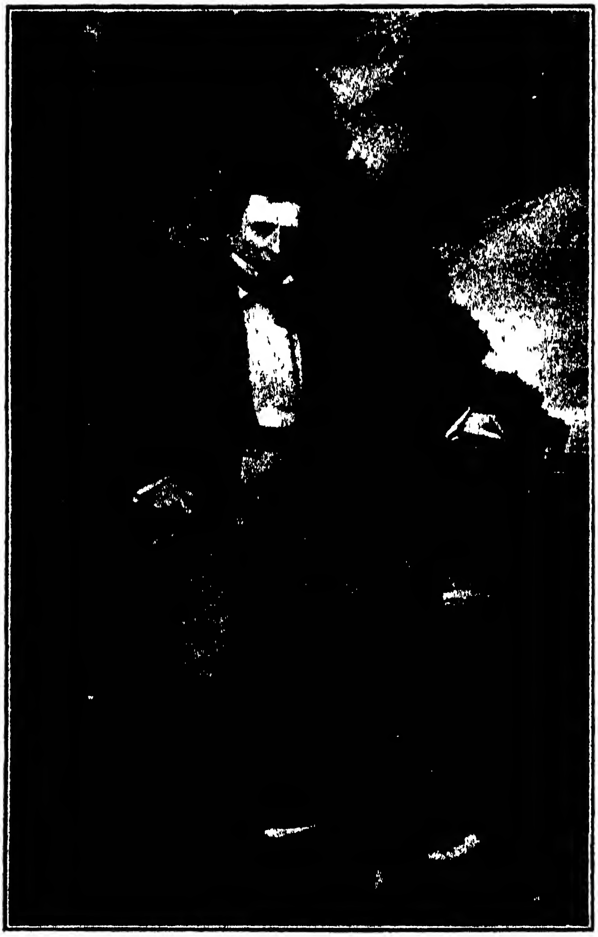
Because of the far-reaching results of his experiments, some comment on them is imperative. As I suggested in the last paragraph, he began in Troy those dealing with the maximum magnetization of iron, nickel and steel which led to new and revolutionary conceptions of magnetic phenomena. As a result, the laboratories of the institute are associated with the discovery and announcement of the principle of the magnetic circuit. In addition to the studies leading to the establishment of this analogue of Ohm's law, Rowland laid at Rensselaer the foundations for his classic re-

JAMES HENRY SALISBURY, '46
James Henry Salisbury (1822–1905). Chief of the Chemical Department of the New York State Geological Survey. President of the American Institute of Micrology.

searches on the magnetic effect of electrostatic charges in motion. At any rate, it is evident that he proposed to von Helmholtz certain procedures which he had not been able to employ because of lack of apparatus Of his work at Johns Hopkins little need be said. While there he completed his investigations relating to the mechanical equivalent of heat Though less original and less daring than those which marked his first professorship, they have been no less useful. At Johns Hopkins, also, he conducted his experiments on magnetic convection. His most epoch-making contributions, however, were those connected with the development of spectroscopy, a field in which he made himself supreme. In addition, however, he devoted his energies to the determination of electrical units of measurement, a subject to which he had been attracted while at the institute. As president of the Congress at Philadelphia, in 1884,

MICHAEL TUOMEY, '35
Michael Tuomey (1835–1857). State Geologist of South Carolina State Geologist of Alabama. Professor of Geology, Mineralogy and Agricultural Chemistry in the University of Alabama.

and the International Chamber at Chicago, in 1893, he aided materially in the evaluation of the ohm, the volt and the ampere Though many of his labors were reflected in the advancement of electrical engineering, Rowland seemed, to the unthinking, remote from practical affairs. Tall and ascetic in appearance, the founder and first president of the American Physical Society, with an intense interest in literature and a passionate devotion to music, he is still regarded primarily as an academician. Nevertheless, though he was a scholar, he was also a mechanician. His accuracy in observation and precision in thought were matched by his inventiveness and mechanical skill, without which his gratings could not have been manufactured. There can be little doubt that, if he had desired, he could have been a great engineer. As it was, he was often consulted on matters of importance. Moreover, during the latter part of his career, he showed by his studies of alternating currents and telegraphic systems that he had never lost his early interest in



DOUGLAS HOUGHTON, '29
Douglas Houghton (1809–1845). State Geologist of Michigan. Professor of Geology, Mineralogy and Chemistry in the University of Michigan.

the applications of science. In all, there is no more significant figure in the history of physics in the United States.

Though there is no such outstanding name as Rowland's among the graduates of the institute who devoted themselves to chemistry before 1875, their contributions to the new learning were highly significant. During the second and third quarters of the nineteenth century, the subject was generally associated with geology and mineralogy; and for that reason it might well be considered with them. By the end of this period, however, it had established its claim to independence. The story of its evolution, as it can be traced in the careers of the alumni who aided in its advancement, is full of in-

ABRAM SAGER, '31
Abram Sager (1810–1877). Chief of the Botanical and Zoological Departments of the Michigan State Geological Survey. Professor of Botany and Zoology in the University of Michigan. Professor of the Theory and Practice of Medicine. Dean of the Faculty.

terest. As with botany and zoology, Eaton's name again emerges. In 1821 he had published his "Chemical Note Book," and in 1822 his "Chemical Instructor." In the list of subjects which he professed in 1824, chemistry stands first. Moreover, in the early bulletins, attention is continually directed to its importance in the world of affairs. In one of these pamphlets, published before either the Lawrence Scientific School or the Sheffield Scientific School had been organized, the preface consists of little more than an extended quotation from one of Liebig's essays. Under these circumstances —especially as Eaton had given, before 1828, thirty courses, each containing at least six hundred experiments—it is not surprising that the foundations of the departments of chemistry in about twenty institutions of high rank were laid by graduates of the institute.

In keeping with its traditions, most of them were attracted by its applications to agriculture or industry, although, in some instances, their professorships did not relate to either. Houghton, for example, was the first professor of the old triumvirate—geology, mineralogy and chemistry—in the University of Michigan. Carr, as I have indicated, introduced the subject in the University of Wisconsin. After eleven years at Madison, where he had also been professor of chemistry as applied to agriculture, he accepted a similar position in the University of California. In the application of chemistry to industry the contributions of the alumni have naturally been even greater. In the early days of the nineteenth century, two of them stand out with considerable distinctness—James Curtis Booth ('31) and Eben Norton Horsford ('38), whose careers were similar in many respects.

After receiving his bachelor's degree from Pennsylvania, Booth, who had little patience with the theoretical demonstrations of *alma mater,* entered Rensselaer. More determined than ever to carry out his plan of making the laboratory "a miniature factory" and the factory "a mammoth laboratory" he spent nine months in Hesse-Cassel and as many more in Berlin and Vienna Returning to America as the first student who had sat under the masters of Germany, he organized in Philadelphia a laboratory for analysis, research and instruction Moreover, in addition to his duties as head of this famous institution, the first of its kind, which is perpetuated by the firm of Booth, Garrett and Blair, he served as professor of chemistry applied to the arts in the Franklin Institute and later in the University of Pennsylvania. In the meantime, however, he had turned aside to geology and mineralogy. As a result of his studies of nickel, which he introduced into the coinage of the United States, of cobalt, of gold and of silver, he was appointed melter and refiner of the mint at Philadelphia. As director, he designed its furnaces, which he improved from decade to decade, and developed many original procedures. All his work, however, was not so directly utilitarian; for in both organic and inorganic chemistry he undertook many researches that were distinctly academic. One of the first presidents of the American Chemical Society, he wrote numerous monographs as well as most of the chapters in his epoch-making "Encyclopaedia of Chemistry, Practical and Theoretical" (1845–50). It is no exaggeration to refer to him as the most distinguished chemist of his day.[1]

[1] For an interesting and valuable sketch of Booth, see Provost Edgar F. Smith's monograph, "James Curtis Booth, Chemist, 1810–1888," n. p., n. d. (Read on September 9, 1922, before the Historical Section of the American Chemical Society.)

Almost parallel with his career was that of Horsford Interested likewise in geology, the latter served under Hall and Emmons. Finally, after a couple of years under Liebig, he was invited to Harvard, where, as Rumford Professor of the Application of Science to the Useful Arts, he induced Abbott Lawrence to establish a school devoted to analytical and practical chemistry. In this, the Lawrence Scientific School, he conducted the first laboratory courses of any importance given in the university. During most of his tenure, it is interesting to note, President Eliot was assistant professor, resigning, when Horsford became head of the Rumford Chemical Works, to establish the department of chemistry in the Massachusetts Institute of Technology. Even after his acceptance of this position, however, Horsford maintained his interest in education, assisting materially in the development of Wellesley College Not only did he endow its libraries and laboratories and provide the material and apparatus necessary for instruction in the physical and biological sciences, but he also introduced a system of pensions for the president and heads of departments as well as an arrangement for sabbatical years in Europe Nevertheless, his chief contributions were made through his patents, which led to the establishment of many successful enterprises; and it is as an industrial chemist that he deserves to be remembered.

Great as have been the services of the graduates in botany, zoology, physics and chemistry, it is doubtful whether they have equalled those in geology and mineralogy. As in the other sciences, the original stimulus came from Eaton Of his surveys in New York, I have already spoken. In addition to his reports upon these surveys, he was the author of four treatises upon geology. These monographs, one of which contains the first illustrations of organic remains, are the prototypes of nearly five hundred studies written by graduates who have followed in his wake Through their contributions it is possible to trace the progress of geology and mineralogy in the United States during the nineteenth century. Indeed, of eleven "events and forces" which, according to Professor H L Fairchild,[2] influenced development before 1848, five were connected with the institute. In the east, the south and the west, its influence was a compelling force in the local bureaus and universities.

During the first part of the period, the New York State Geological Survey occupied a dominant position. At first, in 1836, it was divided into four sections, one of which was entrusted to Emmons, who discovered the Taconic (Cambrian) system, and who, in Troy, Williamstown and Albany, labored zealously in school and college

[2] "The development of geologic science." In SCIENTIFIC MONTHLY, July 1924, xix, 77–101.

for the advancement of his favorite study. The importance of these labors is emphasized by the fact that his old home in the Capitol City—the house in which the Association of American Geologists was projected—now bears a tablet erected by the authority of its lineal descendant—the American Association for the Advancement of Science. A year after Emmons began his work, Booth, in Pennsylvania, became assistant to Professor Rogers In 1837, also, he was appointed chief of the newly organized Delaware State Geological Survey. After the failure of the New Jersey Geological Survey, Cook, who had been assistant and who later accepted the responsibility of administration, made many notable advances in methods of mapping. Though it would be pleasant to follow the alumni elsewhere in the east, their services in New York demand special attention. Of the graduates associated with the State Survey, Hall was undoubtedly the most eminent. Under Emmons, he was assistant in the Second Division. In 1836, he was appointed geologist for the Fourth District, in 1843, paleontologist of New York; and, in 1866, director of the State Museum For nearly sixty-five years—during which time he served as first president of the American Geological Society and as one of the first presidents of the American Association for the Advancement of Science—he was immersed in public affairs. For many years, also, he was professor of geology and mineralogy in the institute With him, or under him, served many graduates, such as Horsford, whom he induced to enter Rensselaer; Carr, with whom he was afterwards associated in Wisconsin, and James Henry Salisbury ('46), principal of the chemical department at Albany and, later, president of the American Institute of Micrology. His reports—filled with echoes of old controversies long since forgotten except by specialists—illuminate every phase in the development of his chosen field in the Eastern States He has been called the "founder of American stratigraphy," the "father of invertebrate paleontology," the "master" without whose discoveries, in the words of James Dwight Dana, "the geological history of the North American Continent could not have been written." In recognition of his unique place in the development of science, the Association of American State Geologists in 1916 placed a tablet on the building which, for nearly fifty years, he used as his office and laboratory.

During this period, the graduates of the institute were not idle in the south. Though Hall refused an offer of the professorship of geology and agricultural chemistry in the University of Alabama, with the promise of a survey if interest could be aroused, and also a position in the Missouri State Geological Survey, he lent material aid, through recommendation or advice, in both Mississippi and

Texas. Other Rensselaer men, however, were personally active. Emmons, in North Carolina, who was engulfed in the maelstrom of the war, was one of the most distinguished. Michael Caleb Briggs, ('35), who had been associated with the Ohio State Geological Survey, joined Rogers in Virginia. In 1847, his classmate, Michael Tuomey ('35) became state geologist of South Carolina; in 1847, professor of geology, mineralogy and agricultural chemistry in the University of Alabama; and, in the following year, state geologist. His reports are among the earliest and the most comprehensive published in the south

In the west, the story is much the same. In 1837, Houghton, aided by Sager, had undertaken the Michigan State Geological Survey. Next year he was appointed professor of geology, mineralogy and chemistry at Ann Arbor. Like Houghton, Hall, who was summoned to organize the Iowa State Geological Survey in 1855, also ranked as first professor of geology in the university. As early as 1841, he had led an expedition into the Middle West to extend the geological boundaries of New York. On this trip he had explored not only Michigan but also Illinois, Indiana, Iowa, Missouri, Ohio and Wisconsin. His thoughts were thus turned westward at an early date. Meanwhile Carr, who had been one of his assistants in New York, and who, as I have intimated, had been called to a professorship in the University of Wisconsin, had become one of the commissioners of the Geological Survey. Through him, probably, Hall became commissioner and, later, superintendent. Of Hall's influence in other states and provinces—for his services were international—Dr. John M. Clarke—like Hall, director of the New York State Museum and long professor of geology at the institute—has touched in his admirable biography,[3] through whose pages move the alumni who made the valley of the Hudson, for no inconsiderable period, a rallying point for the scholars of America.

Any summary of their achievements in the natural sciences ought, however, to include an account of their contributions in fields besides botany, zoology, physics, chemistry, geology and mineralogy; for in some instances they were able to assist materially the younger universities, like Cornell, where Estévan Antonio Fuertes ('61), director of the college of civil engineering and professor of astronomy, erected the Barnes Observatory. Especially should any summary include some reference to those who became teachers in the secondary schools in the towns and cities of the east. Far in advance of their colleagues, some of them, like Fay

[3] "James Hall of Albany, Geologist and Paleontologist, 1811–1898." Albany, 1921.

Edgerton ('26), under whom James Dwight Dana studied in the Utica Museum, realized in their lives the ideals of Amos Eaton. If the accomplishments of these two groups are linked with those of their fellow graduates, the high phrases of the frayed and yellowed catalogues that appear quixotic at times in view of the poverty of the institute and the slightness of its equipment assume a new dignity and a new significance—the dignity and significance of a great tradition informing to-day in every state the spirit of those who have risen to be its heirs.

THE ORIGIN OF LIFE

By Professor CHARLES B. LIPMAN
UNIVERSITY OF CALIFORNIA

AT the remotest frontiers of man's most penetrating and imaginative thought there has always lingered the dream—perhaps the hope—that the age-old mystery of the origin of life would some day be solved The remarkable forward strides that have been taken in the physical sciences in the last two decades, replete with significance for the progress of biological thought and study, have strengthened rather than weakened that hope. It is my purpose in this brief paper to recall to your minds, among other things, some of the theories, or at least speculative hypotheses, which have been put forward in the past to account for the origin of life on our planet, but chiefly to review critically some of the consequences of these hypotheses in order to test the soundness of the latter and to propose a view of my own relative to the problem in hand. To the interested reader, it is probably superfluous to enter into a disquisition on the difficulties of the task in question. Needless to say, finality of judgment in the premises is proscribed and I do not seek to be dogmatic in any part of my discussion. Inconclusive indeed I must be, but I venture to hope that my analysis of the problem may contribute to progress, or at least to clarification of our thought.

The Aristotelian conception of the origin of many forms of animal life from decaying or dying pre-existing forms held sway during the greater part of the period of the recorded history of man. In fact, the theory of spontaneous generation did not receive its death-blow until our own period in man's history had almost arrived. But before the simple and convincing experiments of Pasteur had put the final quietus on the theory of spontaneous generation, many investigators had clearly shown the fallacy thereof. Before the last third of the seventeenth century, Redi had demonstrated that maggots never appeared in meat which was protected from flies, and that only when flies were permitted to lay their eggs in the meat were maggots ever developed there. Redi's findings were challenged by Needham, whose contentions were supported by the high authority of Buffon, but all these objections were shown to be specious by the experiments of Spallanzani, of Schwann, and of Cagniard de la Tour. The investigations just mentioned formed the solid foundation upon which Pasteur built his celebrated struc-

ture of logic and experiment, whose successful establishment led to the death of the theory of spontaneous generation. But has that theory really been annihilated? Are we ready to subscribe to all the implications of such alleged annihilation as well as to the apparent soundness of the arguments against the theory? These questions deserve close investigation and study It is not obvious to many students of biology that the establishment of the proof that the forms of life of which we have knowledge are produced only through the normal reproductive processes of the same or closely similar forms constitutes no denial that other possible forms whose nature lies beyond our ken may not be produced from non-living matter. In other words, it is realized by relatively few people that the theory of spontaneous generation which died so hard might not have been wholly wrong. Its obvious claims and implications were, of course, fallacious, but its more recondite and abstruse inferences, whether fully appreciated by its proponents or not, are not susceptible of banishment without violence to the principles of clear thinking and unprejudiced, critical judgments. One question at least has always remained to confuse and baffle the opponents of the theory of spontaneous generation and that is the following If Harvey's celebrated dictum—*omne vivum e vivo*—is unqualifiedly correct, how can we explain the beginnings of life forms? That question is not regarded seriously by many biologists, because they do not admit that there was any more need for a beginning of living than for a beginning of non-living matter. Many biologists of that school assert that life had no beginning, but has always existed like the inorganic matter in sidereal space. Making such an assertion is, of course, begging the question It is unsatisfying intellectually to be confronted by a hypothesis of that sort Besides, such evidence as may be at hand and the logic concerned therewith are subversive of the view in question. While the establishment of the validity of the theory of evolution does not constitute a decisive denial of the view that living matter had no beginning, it does, at least, supply strong presumptive evidence against such a hypothesis. It would not seem reasonable, in the face of the splendid paleontological evidence which we have of the evolution of some animal forms, to contend against the likelihood that life in the universe did have a beginning and did pass through an orderly development from more simple to more complex forms. But if that is true, does it not seem irresistible to conclude that there must have been very simple forms at the bottom of the evolutionary ladder? If so, how could such simple forms have come to be except by synthesis from the chemical elements or compounds?

With this brief introduction, let us consider the theories which have been advanced to account for the establishment of life on our

planet. The first of these deserving of notice is one known as the Cosmozoa theory, which is built on the assumption that life first came to our planet from other planets. This type of theory in the field in question, first suggested independently by Richter, Helmholtz and Kelvin, is, perhaps, best known through the discussions of Arrhenius in "Das Werden der Welten." As all of you are doubtless aware, Arrhenius assumes that the pressure of light radiation might be considered of sufficient magnitude to overcome gravitational forces in so far as microscopic spores and similar living units are concerned and that such bodies might be conceived in time as drifting from other planets to our own. This would result in the establishment of life forms on our earth with relatively simple beginnings Like the general view to which I have made reference as opposed to the idea that life ever had any beginning, the Cosmozoa theory begs the question and is unsatisfying to the critical and imaginative mind It explains nothing as regards the origin of life. Moreover, it is open to other serious objections The enormous distances in space which must be traversed by these hypothetical "seeds" of this world's life, as we may call them, would require such long periods to cover that it is questionable if the resistance of microscopic spores or other organisms to conditions unfavorable to life for such long periods is great enough to be equal to the ordeal. This argument against the Cosmozoa theory, however, is not as cogent as the one that the low temperatures in interplanetary space would destroy any form of life passing through such space. To offset this criticism, it has been argued that the experiments of Dyer and others have shown that even seeds of the higher plants may withstand the temperatures of liquid air and liquid hydrogen for many hours and still remain viable. But the difference between many hours and many years or centuries is obviously great and the reply to the criticism is, therefore, not satisfying. To be sure, dormant forms of life, as Arrhenius points out, should show prolonged resistance to the conditions obtaining in cosmic space, because of the absence of water vapor and the exceedingly low temperature there, which permit of very slow respiration. But even dormant forms of life must respire and it seems reasonable to conclude that even very slow respiration could not be continued almost interminably at such exceedingly low temperatures as those in question, notwithstanding Loeb's view on that point. In spite of many reports to the contrary, there is no authentic record of viable seeds older than 150 years and there is only one case on record for that length of time. Granted that the conditions in cosmic space would so far diminish the rate of respiration as to give greater longevity to the hypothetical spore, it is difficult to see

how life might be maintained for the long periods necessary to bring life from distant planets to the earth, especially when prolonged low temperatures are probably detrimental even to dormant life forms. More important still is the argument that no case is known in which living cells, dormant or otherwise, have been proved to exist without oxygen. How could we expect spores from other planets to exist in space for centuries without oxygen?

While, therefore, the Cosmozoa theory can not be definitely proved or disproved, I feel that the arguments which I have advanced against it constitute strong presumptive evidence that it is not valid.

The Cosmozoa theory constitutes an attempt to generalize human thought on a great problem It leaves many loose ends and begs many questions. The more modern theories on the subject are more specific than the cosmic theories to which I have adverted. They assume that life had a beginning and with that assumption construct specific hypotheses to account for its probable origin. To a consideration of some of these theories we may now address ourselves The presence of proteins is the distinctive feature of life. The remarkable progress made in organic chemistry in the last two or three decades has not, however, included the discovery of a method for synthesizing proteins As a result, mystery still shrouds the future answer relative to the nature of proteins and hence that of the nature of protoplasm. Because of the fundamental importance and indispensable character of proteins to protoplasm, it becomes pertinent to inquire, if only speculatively, into the identity of organic groups, the radicals of the older organic chemists, which constitute the nuclei, so to speak, of protein compounds and which probably play a rôle in contributing to the amazingly labile nature of the proteins and of protoplasm. With this point of view in mind, Pflüger has pointed out the fundamental difference obtaining between the "dead" proteins, as he calls them, such as egg albumin, and the living proteins which play an active part in the chemical activity of protoplasm. This difference consists in the fact that only the "living" proteins either contain the cyanogen group or can be artificially produced from compounds of cyanogen by subtle changes in the molecular or atomic structural arrangement. Because of this Pflüger believes that the cyanogen group is an integral part of the molecular complex of the living proteins. Since it is possessed of enormous amounts of energy through the large absorption of heat involved in its formation, he argues that it induces energetic internal motion in the protoplasm. Further, on the fact that cyanogen and its compounds are produced only in an incandescent heat, he bases his belief that cyanogen

was the first organic compound characteristic of life which was produced when the earth was still in the incandescent stage of its history. Pflüger then points out there are so many analogies in the chemical behavior of living proteins and cyanogen that cyanic acid may be, itself, regarded as a half-living molecule The tendency of cyanogen compounds to decompose and react again with other carbon compounds at similar temperatures would result in new substances, which, in turn, react with water and salts to form the highly labile proteins of living matter. These were the foundation stones for the construction of highly specialized protoplasmic bodies of living cells, as we know them. In Pflüger's theory, therefore, we see an attempt based on more definite scientific conceptions than those we have previously considered, to visualize a series of reactions by which living matter might be constructed from inorganic matter, with the central and pivotal postulate relative to the behavior of cyanogen and its compounds. It is to be noted particularly, however, that in this theory the beginning of life is still assumed to be in substances of the high complexity of protoplasm, or of the living proteins. The theory is one, then, which proposed to account for the mode of construction of protoplasm, but it does not envisage the problem of the origin of primitive life forms, from the point of view of their antedating the existence of proteins.

Like Pflüger, Benjamin Moore has attempted the formulation of a theory to which the concept of the origin of life from simple inorganic substances is basic. Moore proposes a law of complexity, whose essential feature consists in the assumption that matter tends to assume more and more complex forms in labile equilibrium, so far as its energy environment will permit. Thus oxides, carbonates and similar substances will be produced when conditions are propitious for their formation in accordance with the idea that increasing complexity in the composition and structure of matter is its inevitable destiny. Moore believes that at a proper stage in the earth's development, the temperature conditions were just appropriate in the waters of this terraqueous globe for the formation of colloidal iron and silica. The colloidal iron, as is well known from certain experimental evidence, obtained by Moore and by others, is exceedingly active in catalyzing certain reactions between CO_2 and H_2O in the presence of light, which result in the formation of simple organic compounds. These compounds condense as postulated by Baeyer in 1877, to form the more complex sugars. It may be said to the credit of Moore's view that recent experimental evidence adduced by Baly and Heilbron at Liverpool not only confirms Moore's simple experiments, but amplifies and adds to a marked

degree fundamental information on the experimental production *in vitro* of complex organic nitrogenous compounds, among which was an alkaloid known as coniin It would take us too far afield to consider adequately the Baly and Heilbron experiments and the equally important work of Oskar Baudisch, but I can not leave them without stating my opinion that those contributions are among the most important in the biochemistry of to-day. I believe, moreover, that they will be found to be possessed of a profundity of significance which few scientists realize, or are willing to admit to-day for the solution of the riddle of life's origin. Returning, however, to Moore's law of complexity, we discern in it and its outgrowths the explanation for the formation of atoms, molecules, colloids and finally living organisms, and the heights of organic evolution itself, when a sufficient degree of complexity and a proper orientation of the atoms and molecules has been attained. Let me point out here again, as in the case of Pflüger's theory, that the conception that proteins and protoplasm are essential to life is, in Moore's view, an ineluctable postulate

The other theories which have been proposed on the origin of life are not sufficiently different in essentials from those I have discussed to deserve more than passing mention. F. J. Allen argues that the conditions which are propitious for the maintenance of life must also be the conditions for its origin. On the assumption of the planetesimal theory of the origin of the earth, therefore, Allen believes that life could not have been produced outside the range of the freezing and boiling points of water. At any rate, he believes if life could be produced outside of that range of temperature, it must be very different from the life which we know. Obviously, this must be so, but it is a confession of weakness in the theory. There is no reason, so far as I can see, why a given form of life should be assumed to be the only one deserving of consideration just because our imaginations are not equal to the task of conjuring up some other form of living substance.

Troland's enzyme theory assumes that enzymes produced in some fortuitous fashion became the centers of subtle changes which resulted in the formation of accelerated reactions between the substances soluble in the warm waters of the earth's surface. These would cause the formation of immiscible substances in which the enzyme continued to play the rôle of accelerator until some primitive jelly-like mass with living characteristics would be produced. It is obvious that the Troland theory is vulnerable because it assumes the beginning of life to be contingent upon the existence of an autocatalytic enzyme which is, itself, so complex a substance that chemists have not succeeded in discovering its nature. In other

words, it seems to me that if we are to begin our theory of the origin of life by postulating the sudden appearance of an autocatalytic enzyme under primal earth conditions, we might well postulate the sudden appearance of a living amoeba or even something much more complex.

H. F. Osborn's theories are of far less importance, in my judgment, than those of Allen and Troland, because they add nothing new to the earlier theories. They consist in rephrasing of the older theories and a refurbishing of them with certain observations and experimental data which throw no light on the real problem in hand.

The foregoing discussion has dealt in the main with two points of view in reference to the origin of life on our planet. One is concerned with explaining the beginnings of life on the earth with simple forms, but which, none the less, were composed of highly organized material transported hither from other spheres in the universe. The other conception is that the first living unit originated on our planet through interaction under appropriate conditions of various chemical substances, first simple, then more complex, until a protoplasmic substance with the attributes of life came into being. I desire now to direct your attention to a theory of my own which seems to me to be in greater consonance with facts and with clear reasoning than those to which we have thus far given consideration. It seems to me illogical to assume that such a large gap exists between living and non-living matter at the point of genesis of the latter, as the foregoing theories have postulated. The beautiful symmetry of the series of organic substances known to the chemist would seem to me to argue for a gradual transition rather than an abrupt break between non-living and living matter In order that this may be true, however, it is necessary that simpler substances than protoplasm, or even than proteins, should have become possessors of the attributes of life. I have, therefore imagined that instead of a very complicated bit of protoplasm, no matter how small in size, composed of many, or at least of several molecules, including protein molecules whose structure we do not yet understand, the beginning of life forms was in a living, single molecule, much simpler than the protein molecule. Thus there is no reason, it seems to me, why a single molecule of a substance similar in composition, but different in structure from a molecule of an amino-acid or of a polypeptid, should not have become possessed of the attributes of life long before protein molecules or protoplasm could have been formed. It is well known to those who possess even an elementary knowledge of chemistry and particularly organic chemistry that it is not so much the composition as

the structure of a substance which determines its properties. Thousands of substances are known whose composition in respect to the kinds of elements entering therein is the same, and, in many cases, the elements occur in them in the same proportions and yet the properties of those substances are markedly different from one another. We know that this is because of a different arrangement of the same atoms in the molecule, just as we can make many designs or patterns with one kind of block or brick. But if it is possible to change the physical and chemical properties of substances so markedly by changing the arrangement of the same atoms in the molecule, why isn't it entirely reasonable to suppose that such marked change may go so far as to invest certain molecules with the powers or characteristics which we deem distinctively diagnostic of life? Thus, we can imagine that in the early history of the terraqueous mass which was then the earth, with high temperatures and great chemical and electrical activity existent, such substances as carbon dioxide, water and nitrates may have been caused to combine in such fashion as to produce a pattern of molecule in which the behavior of the substance in regard to motion, growth and reaction with its environment was not, perhaps, the same but, in a primitive way, similar to that of an amoeba, and we would have our first living molecule This molecule would then, under certain conditions, react with other molecules and gradually build up more and more complex chemical aggregates until perhaps after geologic ages, the proteins and protoplasm itself would be evolved.

This view of the problem is, perhaps, rendered more readily comprehensible by a consideration of some facts in the region of life forms. The smallest known units of living matter are single protoplasmic cells known as bacteria But for several years past, we have known that certain bacterial forms must exist which we can not see, because we have apparently reached the limit in the grinding of lenses for magnification with effectiveness. Other tests which are available to us, however, leave little room for doubt relative to the existence of these so-called filterable viruses. For example, by a highly developed technique, bacteriologists have recently succeeded in growing some of these filterable viruses (which are so small as to pass through the pores of some clay filters) on special media in which the colonies of the organisms appear as very tiny dots on the plates. Each colony represents the multitudinous progeny of one original cell which is too small to be visible even under the most powerful microscope. It is noteworthy, further, that this type of investigation has reached its most perfect form to date in the remarkable work of Olitsky and Gates at the Rockefeller Institute for Medical Research in New York, and published recently,

on the filterable virus which is the probable cause of influenza. Other filterable viruses are known whose cells are so small that even their colonies consisting of millions or billions are not visible under magnification We do not even know that some of these infinitesimally small organisms possess protoplasm as do the bacteria and the higher forms. But whether they do or not, they are far removed, as one can readily imagine, from that simple form of matter which we must assume as the primordial form of life if we give heed to a few of the considerations involved in the question to which I have drawn your attention; and particularly to the unlikelihood of any sudden jumps in the evolution of matter which are of such magnitude as those which I have been discussing.

There are one or two further points connected with the subject of this paper which I should like to present. Investigators like Macfarlane at Pennsylvania and others have assumed that plant life must have preceded animal life in point of origin. This assumption is based on another assumption that there could have been no organic substances in the commonly accepted sense of the term without autotrophic organisms to build them. This appears to me to be a gratuitous assumption, since it would seem reasonable to suppose that in a certain part of the earlier history of this earth, temperature and other conditions must have been entirely equal to the production of many series of reactions resulting in the synthesis of a variety of organic substances. From that point of view, therefore, it is entirely conceivable that animals may have originated independently of plants and for all we know, earlier, rather than later, in the earth's history. Another assumption which is frequently made in scientific circles is that nitrogen-fixing bacteria must represent a very primitive form of protistic, if not of plant life. This conception is based obviously on the idea that any organism which possessed the power to synthesize its own nitrogenous foods from elementary nitrogen and other elements must have been the only one capable of existing in a world devoid of fixed nitrogen. But this, it appears to me, is the fallacy of the argument, *viz.*, to assume that there was little or no fixed nitrogen on the earth's surface at a period preceding the "dawn of life." It seems to me that if conditions were ever appropriate for the chemical and electro-chemical reactions by which nitrogen is made to combine with other elements, they were so at that stage in the history of the earth preceding the synthesis of living entities or contemporaneously therewith. Moreover, there is another reason for rejecting the view that nitrogen-fixing organisms were among the earliest of life forms on the earth. If conditions were not appropriate for chemical fixation of nitrogen in the periods in question, then, too, they must have been so for

carbon fixation, and no nitrogen fixation could occur through nitrogen-fixing bacteria without fixed carbon compounds of certain kinds as a source of energy. All claims for the primitive nature of Azotobacter and similar nitrogen-fixing bacteria, therefore, rest on an insecure, and, in my opinion, specious basis.

But if we return to a consideration of the autotrophic organisms, a little careful thought demonstrates the invalidity of regarding them as primitive organisms, even if they originated in the absence of organic compounds on the earth's surface. The green autotrophic plants possess chlorophyll, which seems to be indispensable to their ability to employ the energy of light in synthetic reactions But chlorophyll is a substance of an extremely high degree of complexity in structure It is fairly closely related in that and other respects to the haemoglobin of our blood. The high complexity of its structure, the specialized forms of it exemplified in chlorophyll (a) and chlorophyll (b) argue most emphatically and cogently against the probability that organisms possessing it are to be regarded as primitive On the other hand, there exist a few groups of those wonderful, fascinating organisms known as the autotrophic bacteria which possess no chlorophyll, work in the dark, and yet, like the green plant, can synthesize their foods from simple inorganic compounds with energy furnished by certain chemical reactions which only those organisms, for example, the nitrifying bacteria, have the power of initiating, maintaining and accelerating. But while these organisms must be far more primitive than the green plant when studied from the present point of view, while they are very small and very simple as compared with other organisms of which we have knowledge, they are still extremely complex in that they are to be regarded as tiny, very tiny drops of protoplasm In other words, even when we consider the simplest of known organisms, we are still very far from visualizing the really primitive forms of life, in my opinion.

Without indulging in the subtleties of philosophical method, I have endeavored to draw for you a picture of the workings of the human mind, on the oldest and perhaps most difficult—certainly the most fascinating—of human problems. This discussion is important not only because it aims at the clarification of our thought on the great riddle of the nature and origin of life, but because it contributes to a knowledge of the scientific methods and experiments which must form the groundwork of any rational view on the inceptions of those attributes which we associate with life. The amazing results obtained by physicists and chemists in recent months and years on the intimate structure of the atom and hence of matter itself exemplify strikingly the sublime heights to which

the human imagination and ingeniousness may attain They indicate, moreover, that there is no limit, for all our human weaknesses and limitations, to which human thought may not aspire, in the solution of our most subtle and elusive mysteries.

And thus the world of science moves forward to its certain destinies. With the clear, open, eager and wholesomely curious eyes of youth, it scans avidly and hopefully the horizon which screens the unknown from view. It constitutes itself the rescuer and guardian of the vestiges of the inquiring spirit and exploratory temperament which, with our halting systems of education alone remain in the manhood and womanhood of to-day to remind us of the divine desire to know the causes of things and the truth about things, and is at once the inspiring and engaging, as well as most characteristic, attribute of youth and the freshness of childhood.

Nurtured thus in a spirit of hope and perpetual enthusiasm, the scientist must needs succeed in his age-old quest Such success is bound no less to reward the labors of him who seeks to unlock the secret of life than it has already so bountifully repaid the discoverers of truths, less majestic and grand, less profound and impressive. With slow and measured step the scholar and investigator treads the narrow and difficult trail leading into the unknown There is no dearth of new disciples to continue the search from the point at which the old explorers, fatigued but not daunted, have been obliged to give over their labors. It is with such a vision and in such a faith that we proceed to our appointed task of solving the riddle of life. Who can reflect with intellectual honesty upon the astounding discoveries of physics, chemistry and astronomy and deny that our reward at some point in the future awaits us? Who is so uncritical as to disparage the hope that the mind which can think about its own thinking and sit in judgment on its own judgments can also, somewhere, at some time, rise to the pinnacles of erudition, insight and ingenuity which will render clear its own origin?

I have attempted, I admit very sketchily and hastily, to describe a few of the important views which obtain in the world relative to the origin of life. I have also tried to appraise and criticize those views and introduce an additional view of my own. My purpose was not so much to present dissident views as to examine into the validity of any general view of this most important subject. I do not doubt that I have not made my meaning entirely clear, but if I have held up the mirror so that an occasional image has flashed on your vision in sharp relief, I am content.

DISEASES OF TONSILLAR ORIGIN

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In our laboratory we have been interested in tonsil diseases for several years Since the watchword of the medicine of to-day is "prevention," I wish to point out, briefly, certain principles of preventive medicine and pathology as illustrated by our studies of this organ. Since many of my readers are not medically trained, I shall use as few technical expressions and terms as possible in presenting what I have to say.

My reasons for selecting this subject are, I feel, adequate First, this organ from the standpoint of pathological and bacteriological processes is of peculiar interest and importance, because about it the etiology and transmission of many infectious diseases center. Second, it is of interest because of what already has been done, because of what has been done which should not have been done, and because of what still may be done to prevent and control disease. Again, many diseases of tonsillar origin are of such a character that they lend themselves readily to preventive measures. Nearly all operative procedures in this organ are for the purpose of prevention of disease, thus furnishing a striking illustration of the keynote of modern medicine, namely, prophylaxis.

Permit me just to recount some of the conditions in which this organ is either primarily or secondarily concerned. Acute follicular tonsillitis, commonly called sore throat, is one of the most common diseases. It is caused by a streptococcus. An especially severe variety of this condition is known as septic sore throat and occurs in epidemics, often spread through the. milk supply. You are all, no doubt, familiar with the severer types of this disease under the term of quinsy. Many ordinary colds, including pharyngitis, laryngitis and often pneumonia involve more or less the tonsils. Diphtheria, measles, scarlet fever, Vincent's angina and several other diseases especially contagious in character may be mentioned here as primarily or secondarily involving the tonsils. General or systemic diseases of various kinds have now been traced to the tonsil as a primary focus from which point almost every tissue and organ of the body may be involved. In this connection, acute articular rheumatism and also chronic arthritis along with heart and other complications deserve especial mention,

for these cases when analyzed are usually dependent upon a primary tonsil infection. Two and a half million people in this country suffer from heart disease, and, as Sir Thomas Lewis says, when it is thoroughly grasped that infection has more to do with heart failure than strain or other mechanical defects at all stages of disease, then and only then is the natural history of heart disease understood. Now there are two chief infections which are responsible for heart lesions—syphilis and acute articular rheumatism, and the latter is primarily a tonsil disease. In the examination of the dead body with heart lesions, in tracing back the cause, there are two things we at once investigate, the syphilitic history and the tonsil and rheumatic history.

In the light of the above, therefore, it is clear how important it is to know thoroughly the pathology of this organ which, as it were, occupies the center of the stage in so many important diseases of both children and adults.

The tonsils are prominent accumulations of lymphoid tissue, located on either side of the throat, and covered by mucous membrane which at from eight to twelve points dips down into pockets or crypts to a depth of a centimeter or so. Considered by itself from the point of view of physiology, the tonsil is not an important organ, nor should we expect it to be. It is too superficial and too exposed, for Nature in the course of evolution has seen to it that the important vital organs are deep within the body where protection is greatest, leaving the less vitally important but protective mechanisms (skin, mucosa, adipose tissue, lymphatic nodes) more externally placed. We may look upon it as a part and a very small part of the extensive system of lymphatics of the pharyngo-intestinal system, all of which taken together may possess an important function, but a part and even a large part may be removed without serious disturbance so far as we now know.

Lymphatic nodes may be divided into two groups—first, the lymphatic nodes found along the respiratory and intestinal canal located under the mucosa and covered by a layer of loose, modified epithelium, apparently designed for absorption. Bacteria are always found normally in these nodes. They may be referred to as subepithelial lymphatic nodes. They have no afferent lymph vessels but an abundant supply of efferent vessels which invariably lead to a second deeper set of nodes which are called interstitial lymphatic nodes.

This subepithelial lymphatic tissue is frequently arranged in prominent projecting masses as in the human tonsil and in the Peyer's patches and often the surfaces are corrugated or grooved or pitted; the result being an increase of absorbing or secreting

surfaces. This, too, may be brought about at times by an evagination or tubular depression as occurs in the tonsil of certain animals like the cow and also in the appendix.

The location of the tonsils is strategic; they are prominent masses at the portal of two great systems, the respiratory and the gastrointestinal. We do not know to a certainty that there is any advantage to the body in this location, but we know that from the standpoint of disease transmission, viruses and bacteria of various kinds find it to their advantage to locate here; for as air, secretions, food, etc., pass back and forth over these structures, aided often by such processes as coughing, sneezing, talking and breathing, they are readily carried either to the outside of the body where they may be able to enter another body or deeper into the body, thereby extending their field of activities, all to the decided advantage of the micro-organisms in their struggle for existence.

I wish to call attention now to a point of interest in connection with the distribution of lymphoid tissue in the throat and gastrointestinal canal in relation to the bacterial distribution in these localities. It is well known that lymphatic nodes are so distributed generally in the body as to protect it against the absorption of dangerous matter from various well-recognized sources. Indeed, lymphoid tissue occurs, generally speaking, only in those localities where absorption is occurring. So we have the clusters of lymphatic glands at the hilus of the lungs, of the liver, in the mesentery, in the axillary, inguinal and cervical regions, etc.

When one views the alimentary tract from the lips to the rectum, one observes two localities where striking accumulations of lymphoid tissue appear, namely, in the region of the throat, and in the lower small intestine, especially about the ileo-caecal valve and appendix. The intervening localities, like the stomach, duodenum, etc., have lymphoid tissue, but it is irregularly distributed and far less in quantity. *A priori*, this would indicate excessive absorption of dangerous matter in these localities and as a matter of fact this appears to be true. (Of course, I do not mean to imply that this is the only function of lymph glands.) For in these two localities, namely, the throat and the region above and below the ileo-caecal valve, we find normally the greatest number and variety of bacteria, as may readily be shown by making smear and culture preparations at intervals along the alimentary canal. If one would represent the amount of lymphoid tissue along the canal by one curve and the number of bacteria normally present by another, the two curves would in general parallel each other. Beginning at the mouth, they would rise rapidly, attaining a maximum in the pharynx, would then descend in the region of the esophagus and

stomach, beginning to rise again in the small intestine, gradually approaching another maximum about the ileo-caecal valve, then descending in the lower colon, where many of the bacteria die. In the throat, the tonsils represent the greatest single accumulation of lymphoid tissue, while in the intestine the agminated follicles of Peyer and the appendix represent the same. The significance of these accumulations appears to be that of a protective mechanism against various intestinal substances, bacterial and otherwise.

I will point out here that lymphatic glands are recently acquired structures phylogenetically, being apparently limited to birds and mammals. Tonsils are even more recently acquired, many mammals like the rat, beaver, porcupine, bat and some others not possessing them. There is good reason to believe that bacteria and infectious disease in animals preceded the phylogenetic development of lymphatic structures, so that the view is suggested that this striking distribution of lymphatics in the body, and especially in the intestinal canal may have been determined by the bacterial distribution; which distribution in turn was primarily determined by the anatomical and physiological conditions.

Now in these two lymphatic maxima not only is the normal bacterial flora more highly developed, but here occurs the greatest number of infections. In the throat, streptococcus, pneumococcus, meningococcus, staphylococcus infections, diphtheria, the viruses of numerous exanthemata and other diseases; in the lower intestine and colon, typhoid, paratyphoid, dysenteries, tuberculosis, appendicitis, etc. In the intervening localities relatively few infections occur. The pathogenic organisms often invade primarily the lymphoid structures themselves or the parts rich in lymphoid tissue. In other words, it would appear that in some instances at least organisms become adapted to grow in lymphoid tissue, that is, they attack the very mechanism which the body has apparently designed to protect itself against them. A striking example of this are the hemolytic streptococcus infections of the tonsil. These are acute inflammations of this organ, involving the surface and the crypts and are definitely contagious. The infection is limited quite strictly to the tonsil and is caused by a streptococcus called hemolytic because it has the power to lake red blood corpuscles. The transmission is direct normally through droplets or contact (hands, kissing, tableware, etc.). Another variety of this infection is septic sore throat, which is very severe as a rule. Here the tonsils are infected by streptococci that find their way into the milk either from a person handling the milk or from a cow whose udder has been infected and then serves as an incubator for these organisms. Some years ago we were able to show in our laboratory

experimentally that cows might become carriers of these human hemolytic streptococci when injected into the udder. It is an interesting fact that these streptococci have such a specific affinity for the human tonsils. Between thirty and forty epidemics of this kind of sore throat have now been reported, all traced to milk as a source.

The above observations are quite in accord with a pathological principle more or less general which reveals strikingly the adaptation that continually is taking place between our bodies and bacteria. Other examples may be noted. In typhoid fever, the bacilli primarily attack and invade lymphoid tissue in the bowel and in other parts, and as Mallory has shown, the characteristic lesion in this disease is a proliferation of endothelial leucocytes generally. It, perhaps, would be more proper to speak of typhoid, therefore, as an infection of the lymphatic system rather than an intestinal disease, the intestine simply being the portal of entry. It is another example of a germ having adjusted itself to grow on and invade a protective mechanism; and even though the organisms are always generally distributed rarely localize elsewhere than in lymphoid structures. The same principle is involved in the formation by staphylococci and streptococci of specific substances which will destroy those important defensive cells in our bodies, the leucocytes. These substances are called leucocidins. These bacteria have specialized in the formation of a definite substance which destroys one of our most important defensive mechanisms.

Lymphoid tissue thus may not be equally protective against all bacteria, and in certain infections this mechanism breaks down entirely and instead of being protective it furnishes a fertile soil for growth of bacteria and a route for invasion. The germs may directly attack this tissue and successfully thrive there at least for a time until the body can marshal defensive mechanisms of another order. It is on account of the prevalence of certain infections in this tissue that it may be to the advantage of the body to remove this mechanism or a part of it as is done in tonsillectomy for the prevention of recurrent tonsillitis, or in appendectomy to prevent recurring appendicitis, etc.

A point of importance in connection with tonsil infections is the surface area involved, since this is one factor in determining absorption of organisms and their products. The epithelial surface of the tonsils is many times increased on account of the branching pockets or crypts penetrating deeply into the organ. We have attempted to measure this total surface and find that roughly in an average tonsil of 2 x 1.8 x 1 cm, the entire epithelial surface would amount to about 25 sq. cm, a surface of 5 cm on a side, or roughly

eight times the exposed tonsil surface. Tonsils vary markedly in size, as do also the number and size of crypts; in hypertrophied tonsils, the surface would be far greater than this. Furthermore, the epithelium lining the crypts is loose and spongy, the round cells penetrating the layers even to the surface giving rise to the well-known epithelial structure of the crypts, interpreted and spoken of as a physiological wound. Here, then, is a surface enlarged by invagination and exquisitely designed for absorption. While the extent and nature of the surface are important factors in any infectious process, it should be said that it is not usual for all parts of the tonsils to be equally involved. Individual crypts in a given tonsil vary in the number and kinds of bacteria therein. Some may be nearly sterile, others contain many organisms. In microscopic sections of diseased tonsils certain parts of the organ or more often certain crypts may show marked exudation and change, while other parts or crypts in the same organ may reveal little or no significant alterations.

The distribution of plasma cells in the body is suggestive in connection with infections of lymphoid tissue and especially the tonsils. Generally speaking, these cells are indicative of chronic inflammation or irritation, and most writers regard them as pathologic cells, at least when found in appreciable numbers. They accumulate in masses about centers of chronic inflammation and in general are characteristic of granulation tissue. They appear in many low grade inflammations of the skin and mucous membranes.

The tonsils and crypts become infected by bacteria at birth or within a few hours thereafter. Even pathogenic organisms very early appear, streptococcus pyogenes having been noted as soon as ten hours after birth. The flora of the infant mouth is largely streptococcal.

Using the local accumulation of plasma cells as a possible criterion of the absorption of bacteria or their products, I studied the time of appearance and the distribution of plasma cells in tonsils. Two hundred and forty pairs were examined for these cells. One hundred and eighty pairs were extirpated from children and adults and about sixty pairs came from autopsies on subjects of various ages ranging from fetuses to the very aged. Seventeen were from infants less than three months old.

The results briefly were as follows: These cells are not found in the foetus or the new born. They make their appearance regularly about the second or third week, and are always found thereafter. In children several months old they are constantly found and usually in abundance. They remain present throughout life and even to very old age (88 years) regardless of the anatomic

condition of the tonsil. In pathological tonsils and especially in hypertrophy they are very numerous. They occur under the epithelium of the crypts along the strands of connective tissue and clustered about small blood vessels.

In view of the rôle that these cells play in general pathological processes and since they occur so regularly in tonsils a short time after the entrance of bacteria, one is led to suggest that their presence here indicates a chronic infection focus, where absorption of irritating products is constantly occurring. Aschoff has noted the same in connection with the appendix. Along the entire gastro-intestinal canal, too, one observes large numbers of plasma cells under the mucosa and especially in the region of lymphoid follicles. These facts are quite in harmony with the observations made by Adami and others on the more or less constant penetration of the mucosa by organisms and termed subinfection. No doubt, many bacteria are constantly passing through the alimentary wall into the lymphatics and blood stream, there to be disposed of in different ways. To these bacteria and their products after penetrating the epithelium the plasma cells probably offer the first barrier or line of defense. In the sense, therefore, that the term subinfection has been used in connection with the condition of the so-called normal tonsil, or in the sense in which Aschoff uses the term chronic inflammation in the appendix, so we may regard all tonsils as chronically inflamed a short time after birth. One should, however, interpret such findings in tonsils rationally, and when the terms are used as above they should not necessarily convey the idea of a dangerous or serious pathological state requiring surgical intervention. Nor should they be interpreted as a focus of infection in the sense in which that term is now commonly used.

It became quite evident from some of our earlier studies that more information concerning the pathology and especially the bacteriology of the tonsil crypts should be obtained, and to this subject in our laboratory more recently our attention has been given.

The statement is often made that the flora of the tonsils and the crypts is abundant and varied. This does not appear to be true or true only in a certain sense. By no means will any or every germ that enters the tonsil crypts live and develop there. To determine this, we tested the viability of a number of organisms in the crypts. After first making careful cultures of a crypt for control purposes, a few drops of a live bacterial suspension were injected into it by means of a curved blunt needle. The crypt was then daily cultured. The bacillus prodigiosus after injection gradually became less numerous and at the end of the fourth day had completely died out. *B. pyocyaneous*, a pathogenic chromogen, after injection

caused a slight reaction in the throat lasting a day or two. The organisms gradually became less and by the fifth day had disappeared. *B. coli* will likewise disappear in the course of two days. It is evident from these data that certain bacteria, even those well adapted to grow in certain parts of the body, will not flourish in the tonsillar crypts. In other words, it is not proper, as has been done, to look upon the tonsil crypts as a cluster of media tubes set in the upper part of the alimentary canal growing numerous varieties of bacteria and discharging them into the lumen. As we shall see, the flora of the tonsils is a highly specialized one, restricted quite definitely to a few varieties.

Some years ago, when studying the bacteriology of extirpated tonsils from certain cases of chronic infection, I noted a striking difference between the surface flora and the crypt flora of tonsils. On the surface the predominant organisms were of the streptococcus viridans type, whereas the predominant organisms in the crypts of the same tonsil were as a rule hemolytic streptococci. The exceptions were few. The difference was so striking that at first I attributed great significance to this point, since the hemolytic varieties are so much more virulent as a rule than the other varieties. Later I found that most tonsils, regardless of the associated condition, contained a similar flora. Hypertrophied tonsils, especially, but also others that show no noteworthy pathology reveal the same distribution of the varieties of streptococci on the surface and in the crypts. Pilot in our laboratory recently also examined one hundred tonsils after removal, extirpated chiefly for hypertrophy, though many were normal in size, and found on the surface hemolytic streptococci in 61 per cent. They comprised usually less than 10 per cent. of the total number of bacteria. In the same throats from which these tonsils were removed, cultures taken just before extirpation yielded 43 per cent. positives. Crypt cultures, however, from these same tonsils yielded 97 per cent. positives and in almost all the hemolytic variety was greatly predominant. Furthermore, in another series of twenty-four normal persons cultures from the throat and pharynx in 58 per cent. yielded hemolytic streptococci, and in 19 persons without tonsils cultures similarly made yielded them in 15 per cent., and in these persons were found either bad teeth or tonsil remnants.

It appears from our results that the crypts are an almost constant source of hemolytic streptococci, and this location may be considered in a way their normal habitat. We have not been able to find any other part of the body that so constantly harbors them. The throat, as we have known for a long time, is their chief source and habitat in the body, and it would now appear that it is the

crypts of the tonsils which usually supply the throat with these organisms. From the throat they may be distributed to various parts of the body by contact and otherwise. Or they may be transferred to other persons through the usual channels of transmission of respiratory diseases. In this connection, this point deserves emphasis. Nearly every one is harboring hemolytic streptococci in the tonsils which have not been differentiated from strains that cause serious infections, pneumonias, etc. Some of these strains are less virulent, but not all. Presumably such bacteria may or may not cause arthritis, iritis and other so-called focal infections, but finding them in the tonsil may mean nothing in relation to a possible systematic disease. Should one find abscesses or other definite pathologic lesions in the tonsils, a bacteriologic examination may be of value in determining the cause of an associated condition.

From the anatomic structure of tonsils, one might expect organisms requiring varying degrees of oxygen tension to thrive there. and this leads us to a discussion of certain organisms which grow better in the absence of oxygen, namely, the anaerobes.

There exist frequently in the tonsils peculiar granular bodies. At some time or other they probably occur in the tonsil crypts of every one. They are cheesy-like particles, foul smelling, small gray or yellow, single or more often multiple, lying in the crypts, never in the tissues proper. On microscopic section, they are seen to be made up of filaments arranged in ray-like fashion, suggesting actinomyces. These structures are remarkably uniform. On analysis, they are seen to be composed of four kinds of organisms evidently growing together in symbiosis, namely, leptothrix, fusiform bacilli, spirochaetes and streptococci. The leptothrix grows under anaerobic conditions and in the crypts develops into a cluster of filaments some of which radiate to the periphery, forming central stalks about which fusiform bacilli are arranged perpendicularly, closely resembling the structure of a test tube brush. Scattered throughout this growth are very large numbers of spirochaetes and streptococci. The streptococci in these masses have recently been studied in detail by Pilot and the writer. They are both hemolytic and non-hemolytic. The hemolytic are aerobic and quite like the varieties that occur commonly in the throat. Many of the non-hemolytic streptococci are distinctly anaerobic when first cultivated. They exhibit a green halo on blood agar plates and if the initial cultures are not made anaerobically they will not appear. After a few transplants under aerobic conditions, however, they will adapt themselves to grow well and soon equal the anaerobic growth. This anaerobic property of the green strains is very definite and is readily discernible in the first series of cultures. They are not

highly virulent for rabbits, being comparable in this respect to the ordinary streptococcus viridans of the buccal mucosa.

On the teeth along the gum margins appear constantly similar radiating growths made up of the same four varieties of organisms. They compose a considerable part of the tartar on the teeth. When removed, the growth returns again in two or three days. In the lower intestinal canal and also about the genitals are two other sources of these organisms where at certain times they thrive abundantly.

Having considered briefly the normal habitat and distribution of these organisms, I will now say a few words about their relation to disease. These organisms are opportunists and like other germs about the body will, under certain conditions, cause serious infections. The conditions under which they do this are manifold. They are prone to develop in tissues which for any reason have lost their vitality, for example, in persons who have suffered from other diseases and especially when tissues have been injured by wounds, foreign bodies, vascular changes, tumors, severe infections, anesthetics, etc. So as a result of the growth of these germs, especially the spirochaetes, fusiform bacilli and streptococci, there arise infections about the throat like Vincents angina, gangrene about the mouth or face called noma, growths on the tonsils known as pharyngmycosis, putrid infections of the middle ear, and various lung infections characterized by a very foul odor of the breath and sputum like pulmonary abscesses, putrid bronchitis and empyema. In the intestinal canal, also, similar putrid infections arise sometimes, causing appendicitis and colitis; and about the genitalia at times serious gangrenous lesions arise as a result of infections by these same organisms which, as before stated, often occur normally in these localities.

In conclusion, I wish to say a few words more specifically about the prevention of tonsil diseases. Operation on the tonsil is nearly always the simple removal of the organ and is done for *preventive* purposes, in contrast, therefore, to so many operations whose primary purpose is curative. When the indications are clear it is one of the most logical and satisfactory procedures. Acutely diseased and highly inflamed tonsils are not removed, the operation being postponed until the inflammation subsides.

The clearest indication is recurrent tonsillitis, serious enough in itself but so often leading sooner or later to arthritis and to other diseases, especially the heart. Chronic infections which we now speak of as focal infections are clear indications, when it can be determined that the tonsils are the source of the trouble. But I may say that many of these cases present diagnostic problems of the very greatest difficulty.

Acute articular rheumatism is nearly always primarily a tonsil problem, and the indication is clear for tonsillectomy, especially after the first attack. Many workers believe children's diseases, like scarlet fever, measles, etc., are not so severe or complications are less apt to follow in those whose tonsils are removed. It has been found too that in diphtheria carriers enlarged and diseased tonsils occur in a large percentage.

With reference to the fuso-spirochaete-streptococcus combination in the tonsils and about the teeth, since we now know more about their haunts, we should expect to be able to formulate a more rational prophylaxis. While it may be out of the question completely to disinfect the mouth or the tonsils, the number of bacteria harbored there may be greatly reduced by various procedures. In dealing with organisms of this type, diminishing the dosage of bacteria generally is an important element in prevention. Removal of the tonsils and drainage of the crypts containing these granules are rational procedures to pursue relative to the hygiene of the tonsil. Thorough and frequent cleansing of the teeth, especially between them and about the gums, removal of tartar and of pus pockets, and in general the establishment of a clean normal healthy mouth and throat would clearly be indicated in this connection. Especial precautions should be exercised in persons about to undergo anesthesia for any purpose, but especially in tonsillectomy or other operations about the mouth or throat where danger of fuso-spirochaete lung abscess and pneumonia exists.

One may well ask if there is not a single good word to say for the tonsils. One of the best tests both of the function of any organ and also its relation to disease is to remove it in a very large number of cases and observe the result. This has been done with the tonsils. A few writers have thought that in those whose tonsils were removed early in life an adenitis was more prone to develop. Digby especially has tried to make out a case for the tonsils and subepithelial lymphatics as tissues that primarily are concerned with establishing an immunity in health, which appears to be a very plausible assumption. But even so, the tonsils are relatively so insignificant in comparison with the very large amount of lymphatic tissue in the throat that its absence would probably not materially affect this process, assuming that it occurs.

On the whole, data of this character are meager in comparison with the overwhelming evidence that it is possible to array against the tonsils as dangerous foci of disease. It is about as difficult to defend them on the grounds of usefulness as it is to defend the appendix. It appears from what we now know that if we were born without tonsils and appendix, we would lose nothing, and the risk

of living would be materially diminished. Removal of the organs apparently accomplishes this purpose, but, of course, dangers of operative procedures must be considered. Complications may result occasionally, such as hemorrhages, lung abscesses, post-operative pneumonia, etc., but such accidents are subject to control and should be very largely eliminated by care and further research.

It should be realized that the safest position for the medical man to assume with respect to operations in general and especially with respect to the removal of organs is that of a progressive conservatism. It is safer to act upon clear indications when they arise, even though occasionally the consequences may be serious, than to indulge in the more or less wholesale removal of organs, whatever may be their supposed function.

WILHELM HOFMEISTER

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Of all the great men of botany in the nineteenth century the career of Wilhelm Hofmeister was the most phenomenal. Without a university training, without the help of a teacher in research, he lifted himself into recognition as one of the foremost men of science of his time. Without previous university connections, he was advanced by a single step from the status of a tradesman to that of a professor of full rank in the University of Heidelberg—the oldest university of Germany. This was a tribute to the extraordinary attainments of the man.

In view of his great eminence, it is difficult to account for the scarcity of biographical sketches and "appreciations" of Hofmeister. At the time of his death, in 1877, the scientific periodicals contained only brief notices of his life and botanists of to-day have found difficulty in locating a satisfying sketch of Hofmeister and his labors written by one of their own craft.[1]

Since he attained such eminence the facts about his education, his worldly circumstances, his advantages and limitations of environment, the conditions under which he did his work, etc., acquire an especial interest. Hofmeister was essentially a self-made man; no especially favorable circumstances were responsible for his advancement; he was not the product of his environment but of his heredity. He was gifted with a penetrating mind, he showed great capacity for work, fixedness of purpose, and apparently reached many of his conclusions by the "intuition of genius." One circumstance that doubtless favored his output was the love and congeniality in his home life.

In the account of his life which follows I have drawn largely on the narrative of Pfister, who obtained many of his facts from the Hofmeister family.

Wilhelm Friedrich Benedikt Hofmeister was born in 1824, at Leipzig, where his father was a highly respected bookseller and

[1] A sketch of Hofmeister, with portrait, was published in *The Plant World*, 1905. This was a translation from the German of Professor Göbel by Professor Francis E. Lloyd. The most comprehensive memoir on Hofmeister and his scientific work is by Ernst Pfister in "Heidelberger Professoren aus dem 19 Jahrhundert," Vol. 2, pp. 267–378. For portrait different from that in *The Plant World*, see "Acta horti Bergiani," Vol. 3, and Fig. 135 in the writer's forthcoming book "The Growth of Biology."

occasional publisher. He inherited from his father an interest in botany and from his mother a keen mind. His earliest instruction outside the home was in a private school, from which he entered the newly-founded Realschule of Leipzig. This institution had been established in 1834, by Dr. Karl Vogel, a friend of the elder Hofmeister. Vogel was a competent teacher, with fresh ideas of education, and emphasized a kind of mental training that led students to think for themselves. In 1839, at the age of fifteen, Wilhelm Hofmeister left the Realschule and ended his education under the direction of masters. His further attainments were the result of self-education; but it must be remembered that he was especially acquisitive and original. He immediately reviewed the principal subjects he had pursued at the Realschule (physics, chemistry, algebra, trigonometry, geography, etc.) and added to them. He lacked the much valued classical training of the German Gymnasia, but the powers of his mind had been improved by methodical training in those subjects which he had pursued at Vogel's Realschule. Having a natural taste for music he learned to play the violin without a teacher and he began to take an active interest in the study of plants and insects, stimulated thereto by his father and some of his learned friends.

In the summer of 1839, just after leaving the Realschule, he entered the musical establishment of Cranz at Hamburg as "Volentar"—an apprentice or unsalaried clerk. This has given rise to the statement in some cyclopedias (Britannica, etc.) that he was by occupation a music dealer—this connection, however, was only a temporary venture engaged in between the ages of fifteen and seventeen. From the age of seventeen, for 22 years (1841-1863) he was in his father's bookselling establishment at Leipzig. The article in the New International Cyclopedia says he was a "druggist," but of this I find no authentic record. At Hamburg, his mornings were relatively free and he employed his time in a review of his previous studies, in taking lessons on the violin and in excursions on foot and by boat in the vicinity of Hamburg.

In 1840, Hofmeister's father acquired a property at Reudnitz in the suburbs of Leipzig, comprising a house and a garden in which he arranged plants according to the natural system. At first the house was used as a summer residence, but was soon converted into a family dwelling occupied by the parents, their children with their families, and for some time four families of Hofmeisters lived happily and in harmony at this parental domain. Here Wilhelm Hofmeister brought his wife in 1847; here were born five of his children, and here he carried on his investigations and prepared his monumental publications. In 1841 he entered his father's

firm as foreign correspondent and was connected with the business until his call to the University of Heidelberg, in 1863. At first he had some leisure to devote to his studies, but very soon, the business at the Leipzig store so occupied his time, that, as he himself said, his only regular working hours in science were from four to six o'clock in the morning. In the Hofmeister household, love, congeniality, simple living and high thinking prevailed. The families living there had friendly social relations with a few kindred spirits of learning and culture, and all this was helpful to the development of Wilhelm Hofmeister. He had formed a friendship with Professor Reichenbach, of Hamburg, who encouraged him. He was also greatly influenced by reading Schleiden's "Outlines," which directed his attention to microscopic botany and to the embryology of plants. In this field of work his extreme nearsightedness was not a handicap but in some ways an advantage in the handling of minute objects and in making thin sections for the microscope. It speaks well for his sharp mental discrimination that, at this early age, he pronounced the work of von Mohl of higher quality than that of Schleiden.

In 1847 he was married; the same year he published a scientific paper, the next year another one, and, in 1849, there appeared his first work of commanding importance, the treatise on the origin of the embryo of Phanerogams, published as an independent brochure by his father. This work attracted such wide attention in the scientific world, as well as among botanists, that, in less than two years after its publication, the University of Rostock conferred upon him the degree of Doctor of Philosophy *honoris causa,* thereby extending the first formal recognition from the university world of his high standing as an investigator. The Royal Saxony Society of Science, at Leipzig, elected him to full membership.

He was now working with intense application, and in 1851, his father's firm published another independent work. This was his famous path-making treatise entitled "Comparative researches on the germination, development and fruit-formation of the higher cryptogams and on the seed-formation of the conifers." This was the high-water mark of his achievements—a research so brilliant that it led von Sachs in his history of botany to exclaim: "The results of the investigations published in the *Vergleichende Untersuchungen* in 1849 and 1851 were magnificent beyond all that has been achieved before or since in the domain of descriptive botany; the merit of the many valuable particulars, shedding new light on the most diverse problems of the cell-theory and of morphology, was lost in the splendor of the total result, which the perspicuity of each separate description revealed to the reader before he came to the

conclusion of the work, and there a few words in plain and simple style gave a summary of the whole." The significance for botanical science of these two works will be spoken of later. The treatise of 1849 was dedicated to Hugo von Mohl, that of 1851 to "*Seinem treuen Vater in Liebe und Dankbarheit*," which reminds one of the famous filial tribute of Pasteur in the dedication of one of his chief works to his father.

After 1851, as products of his great activity, researches along the same general line continued to appear and his friends began to fear that he would break down under the strain of business cares and activity in research. Then came, in 1863, a signal recognition of his distinguished services to the progress of scientific botany; this was an invitation to accept the professorshp of botany in the University of Heidelberg. It is to be remembered that the practice and traditions of German universities were so conservative that, except in the Faculty of Medicine, it was unprecedented for a man without previous university connections to be called to a professorship. Hofmeister had never even attended a university and from the age of fifteen to thirty-nine had been engaged in trade. These factors were against him, and it was purely on the basis of extraordinary merit that he was seriously considered for the position. Hofmeister was not nominated in the usual way by vote of the philosophical faculty, but owed his nomination to the Grand-Ducal Ministry of Baden. In 1854 Professor Reichenbach died at Heidelberg, and the philosophical faculty named von Mohl as its choice to succeed him. Owing to circumstances, however, the call was not made, and in the interim the position was held by the adjunct professor, Anton Schmidt. In 1861 members of the faculty took a new vote and named de Bary as their choice, but this action did not result in a call. In May, 1863, the Grand-Ducal Ministry said to the faculty, if their vote of 1861 was not carried out, that the ministry would nominate Dr. Wilhelm Hofmeister for the position. They spoke of their candidate as follows: "He impresses us as one of the foremost botanists of Germany, as a man of genial disposition, of great technical skill and active productivity, who for the first time shows an inclination to accept an academic position, and also at present has the certain prospect of a call to Hamburg." Notwithstanding some misgivings expressed by the faculty, he received this appointment, and, in the fall of 1863, moved with his family to Heidelberg, entering the university with full rank as Ordentlicher professor of botany and director of the botanical garden.

From the accounts of Goebel and Pfitzer, two of his botanical contemporaries, Hofmeister was a likable personality, alert and interesting. "His appearance had in it nothing of the German

type; he looked like a southern Frenchman. Of small supple form, he possessed a dark, clear-cut and uncommonly vivacious face; he was always bubbling over with activity and ever showed great kindness to his students.''

As a lecturer in the university, Hofmeister overestimated the state of preparation as well as the earnestness of general students of science, and placed his lectures on so high a plane that he emptied the benches of his lecture room of the miscellaneous students in pharmacy, in pre-medical studies and in general science, but he held the attention and secured the admiration of the more advanced and serious-minded. Among the men who worked under him, either at Heidelberg or at Tübingen, we find the names of Askenasy, Engelmann, Goebel, J. Knauth, Krutitzky, Millardet, N. J. C. Müller, Pfitzer, Rosanoff and Zacharias.

He was especially expert in laboratory instruction and made before his students microscopic preparations of remarkable fineness. With his colleagues on the faculty he showed himself a good companion, a ready and interesting talker of wide intelligence, and made many personal friends. Owing to a variety of small causes involving differences of opinion the faculty at Heidelberg became divided into two camps; Hofmeister had friends in both, and being too sincere to dissemble, his friendships became strained in some quarters, and his life there was made unhappy. He was further distressed by sickness in his family, and within a year suffered the grief of losing his wife and youngest daughter by tuberculosis. He was now (1872) called to Tübingen to succeed Hugo von Mohl, and gladly accepted this opportunity for change of environment. Having been at Heidelberg nine years, he was destined to hold the professorship at Tübingen for only four years, and thus ended his entire university career within thirteen years. His two favorite sons, aged, respectively, twenty-three and twenty-five, died of tuberculosis, both in 1875.

In 1876 he himself suffered a stroke of apoplexy and was obliged to resign from his professorship; he passed away at Leipzig in 1877.

We come now to consider Hofmeister's scientific publications and their influence on botany. There is a marked unity of purpose in the rather numerous scientific memoirs of Hofmeister. They are not disconnected pieces of work, containing discoveries of miscellaneous facts, but for the most part they form a series of program-studies extending over a number of years, and directed towards the solution of definite problems.

In 1847, he began a series of publications which extended to 1860, on the origin of the embryo of the flowering plants, including fertilization of the egg and formation of the embryo. The first of

these papers to attract wide attention was published in 1849, on the origin of the embryo in the Phanerogams. This paper with the German title "Die Entstehung des Embryo der Phanerogamen," occupies a central position in the series on the embryo of the Phanerogams. It is a famous botanical document, published as a separate work of 89 quarto pages, and 14 copper plates embracing not less than 429 figures.

There is a characteristic directness about Hofmeister's style which requires close attention in reading. His writing is dignified, straightforward, and impresses one with the remarkable clearness and certainty of his observations. His brief critical remarks are in marked contrast with the boastful and exaggerated tone of Schleiden.

The work of 1849 starts abruptly with a description of observations and without any preliminary remarks. At the end there are nine pages of a clear and concise summary and conclusions in which he shows that the 38 plants of 19 genera examined all agree in essential features as to their method of fertilization and embryo formation, and he expresses the belief that these phenomena are the same for all phanerogams. The facts assembled in this paper undermined the pollen-tube theory of Schleiden, and in 1855 he published decisive researches which accomplished the complete overthrow of Schleiden's contention. About 1840, one of the questions that vexed the botanical world was the origin of the embryo in plants. Schleiden maintained that the embryo arose from the tip of the pollen-tube—thus making the embryo-sac a nidus within which the end of the pollen-tube was nourished into an embryo plantlet. Hofmeister showed that the pollen-tube carries elements of fertilization and that the embryo is formed from an egg-cell already existing within the embryo-sac developed within the ovule. He traced the origin of this egg-cell showing that a substance carried by the pollen-tube fertilizes the egg, and how the embryo develops within the ovule out of this fertilized egg.

In these observations he had been in a way preceded by Amici and Robert Brown, but Hofmeister's observations were so extensive and exact that Schleiden's observations on these points and his theory of formation of the embryo were set aside. Hofmeister not only traced the origin of the egg within the ovule, but also showed the development cell by cell of the embryo.

The work published in 1849 on the embryo of the flowering plants was merely the starting-point of a larger enterprise. Already, before its publication, Hofmeister was engaged in similar investigation of the lower plants. Although some of the main facts in the life-history of ferns and mosses had been made known, the crypto-

gams had been quite generally neglected in botanical investigations. Ignorance of cryptogamic botany was, indeed, the chief cause for the long delay in discovering a unity of relationship throughout the vegetable kingdom. Hofmeister made his studies comprehensive, including the lower as well as the higher plants, and he erased the line of demarcation that was supposed to separate the cryptogams and the flowering plants.

From his comprehensive studies there resulted "that great general pronouncement" first published in 1851—the most remarkable single piece of scientific investigation of the period—a work which F. O. Balfour says "will always stand in the first rank of botanical books." Its long title, however, is not alluring: "Vergleichende Untersuchungen der Keimung, Entfaltung und Fruchtbildung höherer Kryptogamen und der Samenbildung der Coniferen," a book of 179 quarto pages and 33 copper plates, published in Leipzig by his father's firm. After its publication there followed a number of further researches along the same line, extending his observations to other plants and making clearer and fuller his conclusions. At the request of the Ray Society of London, he combined his various researches of this nature into a uniform whole, "revising the text throughout and adding a quantity of matter existing in manuscript." This assembled product appeared in English translation in 1862, under the title: "On the Germination, Development and Fructification of the Higher Cryptogamia, and on the Fructification of the Coniferae." The original publication of 1851 is difficult to obtain, and I have been obliged to use only the readily accessible English translation. It is more extensive than the original in 1851, making a volume of 491 octavo pages of text, with 75 plates and more than 1,100 figures.

By extensive observations Hofmeister demonstrated the existence of an alternation of a sexual with an asexual generation in all plants, from the lowest to the highest, which made necessary some sort of theory of their community of descent. These two points require some further elucidation.

The term, "alternation of generations," had been introduced into biology by Steenstrup, in 1845, to apply to those cases in animals where a generation arises by budding from parent-forms which is very different in appearance from the parents, and this generation, in turn, gives rise by a sexual process to the parent-form. This is well illustrated in the hydroid polyps, where a colonial branching form sets free by budding, medusoids which as independent jelly-fish swim freely and lead an independent existence. This generation of medusoids produces eggs and fertilizing agents, and their offspring resemble the original parent form, but

not at all the generation of beings from which they have sprung. The alternation of generations in plants is only generally similar to this process, but it extends to them all. By the germination of the spores of ferns, for illustration, there arises a plant which produces the sexual elements and from the union of these there develops a generation similar to the original plant. Furthermore, this phenomenon, although obscured in the higher forms by the production of seeds, is common to all plants. Says Goebel, in 1905, "This is, in very truth, the greatest discovery that has ever been made in the realm of plant morphology and taxonomy."

Another sweeping conclusion resulted from Hofmeister's "Comparative Researches"; they revealed all plants as genetically related; no longer could individual plants be looked upon as separate creations, or entities; the lower forms were shown, by their structure and method of development, to merge into the higher forms making a unified series. Thus, almost automatically, the conception of the community of descent of plants took its place. This interesting fact is of historical importance in connection with the rise of the theory of organic evolution. In 1851, fully eight years before the publication of Charles Darwin's "Origin of Species," a theory of community of descent of plants had been made necessary by the illuminating researches of Hofmeister. Darwin's publication made it general, and, after 1859, it applied to both animals and plants.

How directly Hofmeister arrived at his points is shown by his giving (in the English translation referred to) only eight pages of review and general conclusions, after 433 pages of scientific results. Hofmeister is not confused by the often perplexing conditions brought out by his researches on individual plants; with remarkable clearness he picks out the corresponding processes; he shows that a uniformity exists between the fruit-formation of mosses and the embryo-formation of higher cryptogams, and that the formation of the embryo of gymnosperms is intermediate between the higher cryptogams and phanerogams. In the cryptogams the fertilization is accomplished by free swimming spermatozoa, in the conifers and angiosperms by a pollen-tube, within which nonmotile spores arise and effect the fertilization.

Here, by the phenomena of similarities in respect of fertilization, fruit-formation and embryo-formation, all plants from the lowest to the highest are united into an unbroken chain. Hofmeister says: "The phanerogams therefore form the upper terminal link of a series, the members of which are the Coniferae and Cycadeae, the vascular cryptogams, the Muscineae, and the Characeae. These members exhibit a continually more extensive and more independent vegetative existence in proportion to the gradually descending rank

of the generation preceding impregnation, which generation is developed from reproductive cells cast off from the organism itself."

After going to the University of Heidelberg, Hofmeister published, in 1868, his "Algemeine Morphologie," introducing into morphology a new conception somewhat similar to the experimental morphology that in later years was extensively developed by zoologists. But the idea of Hofmeister of the dependence of plant organization on inner and outer conditions has, as Goebel suggests, been too little followed up by botanists.

He projected a handbook of plant physiology with the collaboration of de Bary, von Sachs and several other botanists of high standing. Hofmeister was designated as editor, and, although he supplied and published most of his share, the enterprise as a whole was never completed. In addition to the works mentioned he published an excellent treatise on "Lehre von Pflanzenzelle" and some observations on the physiology of plants. Out of his whole scientific product the publications of 1849 and 1851 stand forth in relief as the best known and as containing his most notable and fruitful work.

Hofmeister's discoveries and conclusions changed the outlook and entered largely into all future progress of botany. Besides his many individual contributions to the knowledge of plants he will be remembered for three outstanding generalizations:

(1) He demonstrated the true nature of fertilization in flowering plants; observed the origin of the ovum and the formation of the embryo cell by cell. These results were published in 1849.

(2) In 1851 he published his observations on the fertilization and fruit-formation of higher cryptogams and the conifers, connecting these results by broad comparisons with his observations on the angiosperms. This publication embraced the discovery of alternation of generations throughout the vegetable kingdom.

(3) His comparative studies made necessary for all plants a theory of community of descent.

After Hofmeister we enter the modern era of plant study and, since no one except a professional botanist can adequately write the history of its more recent developments, this is a convenient point to leave the story of the growth of biology from the botanical side. There remains, however, certain advances of the nineteenth and twentieth centuries that are broadly biological. Such topics as the cell-theory—the result of the work of both botanists and zoologists—and the rise of a separate division of biology, named cytology, belong to this category; also such general advances as the experimental study of heredity and discovery of the laws of inheritance.

These experimental studies, first (or at least very early) carried out by Mendel on plants, became the starting point, at the opening of the twentieth century, for active investigation of both botanists and zoologists, and gave rise to the subject of genetics. Furthermore, the work of Pasteur was so broadly biological in character that in following it up, botanists and zoologists were drawn into one circle of investigation. The doctrine of organic evolution, in which Hofmeister was a pioneer on the botanical side, is likewise a field where botanists and zoologists met on common ground.

PROGRESS IN METHODS OF INQUIRY AND RESEARCH IN THE SOCIAL AND ECONOMIC SCIENCES

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The object of this paper is to critically examine methods of research used in the social sciences. The term "social sciences" is here used to include economics, political science and sociology. Results of research will be mentioned only as they illustrate advances in method. Since the subject-matter of the paper must of necessity be somewhat abstract in nature, it may be helpful at the outset to outline the manner of treatment. The method of scientific induction will first be considered. Difficulties in the use of scientific induction in the social sciences will next be considered. There will follow a discussion of specific ways in which these difficulties have been or may be overcome by the use of three methods of social research. The relation of the three prevailing methods of social research to the scientific method will then be considered and, finally, some of the typical organized agencies conducting scientific research will be mentioned.

Pearson[1] has made the point that whatever may be the diversities in subject-matter of the different sciences, the scientific method is always and everywhere the same. If this be true, then there must be some simple skeleton of procedure back of and common to such variations in scientific method as are commonly indicated by the terms experimental, analytical, statistical, synthetic, inductive, objective, deductive, classificatory or descriptive method.

THE METHOD OF SCIENTIFIC INDUCTION

The following formulation of scientific method into four consecutive steps has been useful to me as a test of scientific research:

First step: formulation of a working hypothesis of investigation.
Second step: collection and recording of the facts of observation.
Third step: classification of the facts of observation.
Fourth step: generalization from the facts of observation.

This enumeration of the steps of scientific inquiry also embraces all the variations in method mentioned in the preceding paragraph,

[1] "The Grammar of Science," 2nd Ed., 1892, p. 6.

or more specifically: observation should be analytical and descriptive; the experimental method is merely observation made under conditions of control; measurement of the phenomena observed should be in objective terms or units; classification is partly an analytical and partly a synthetic process; the series of steps is itself a statement of the inductive method; the use to which the final generalization or law is put in explaining some particular occurrence is deduction, and deductions from inductive generalizations established in this way form the reliable predictions of science.

Social scientists have been justly criticized for not using this method of scientific induction and for over-fondness of making deductions from hastily formulated hypotheses that have never been subjected to the test of sufficient facts of observation. Critics have held that, so long as social scientists were content with semi-philosophical generalities based upon impressions rather than upon facts of observation, their fields of study could not be regarded as organized scientific knowledge, but that as soon as scientific induction, in contrast to speculation and empirical thinking, was adopted, scientific progress would result. Social scientists have certainly not been unacquainted with scientific induction; yet they signally failed in its use. This failure appears to have been due to certain logical pitfalls that have not been avoided. Let us consider briefly these pitfalls, step by step.

In the first place, working hypotheses are often suggested by analogy, although analogies are proverbially dangerous in scientific work. It has often been forgotten that an hypothesis is a purely provisional formulation, tentative in character and subject to revision by the acid test of facts. Further than this, there has been a tendency to confuse hypothetical units postulated for convenience of analysis with real data of observation.[2] Many economists, political scientists and sociologists have fallen into this logical error when using the term instinct. The term instinct is a word used to describe (among human beings, at least) a hypothetical form of behavior. Many social scientists then pass insensibly to the position of accepting the abstraction itself as datum of observation, although no measurement of the phenomena has been made. The concluding fallacy is to arrive at a generalization based on this false logical process, and to believe that a scientific law has been established.

In the second place, much of the data of observation that has been collected in social science is worthless. The reason is that observations are frequently recorded in subjective or in qualitative terms. To be of scientific value, observations must be recorded in

[2] Faris, "Are instincts data or hypotheses?" *Amer. Journal of Sociology*, Vol. 27, No. 2, pp. 184–96.

objective and, if possible, quantitative terms. Moreover, little effort has been made to discriminate between compensating and cumulative errors of observation.

In the third place, the act of classifying has been performed as though it were an end in itself. The result has been that elaborate systems of individual and largely subjective categories of classification have been promulgated By contrast, the need is urgent for *a posteriori* categories of classification, *e g.*, of categories that grow out of the common traits of the phenomena studied.

In the fourth place, social scientists have been too prone to easy generalization. I have already indicated in my discussion of the logical pitfalls of hypothesis-making how generalizations based on hypotheses instead of data are confused with true inductive generalizations. The result is seen in the well-defined tendency in much of present economic, political and social theory to refinements of distinction that are of purely verbal character. Finally, one can not help feeling that this prevailing tendency to speculative thought which social scientists "first scorn, then pity, then embrace," is dangerously like the effort of the day-dreamer who seeks in fantasy an escape from a too cruel reality If *verification* were insisted on in social science to anything like the degree it is in physical science, some of our theorists would have a rough awakening.

But at this point, a word of warning should be said, lest we conclude too easily that the process of scientific thinking is that one perfect thing. It can be shown that speculative thought (running to fantasy and day-dreaming) is not an inherently different kind of thought from scientific thinking, but is only relatively different. Bias is present, or likely to be present, in each step of scientific thinking, for desire determines the selection of memory images that are put together to form the hypotheses; it influences the selection of facts to be observed, the grouping of those facts, the inferences drawn therefrom and also the resulting predictions of future events.[8] Consequently, it becomes a question of continual guard against bias, rather than of taking some formula or thought pattern that will be fool-proof.

Difficulties in the Use of the Scientific Method

This brings us to a consideration of the difficulties of using the scientific method in studying social phenomena. Bias or prejudice is an emotional attitude towards facts or things such that our speculations, observations and inferences are unduly warped from objective truth.[8] Since the subject-matter of social science is not the

[8] Ogburn, "Bias, Psycho-analysis, and the Subjective in Relation to the Social Sciences," Publ. Amer. Sociological Society, Vol. 17, 1922, pp. 62–74.

realm of the inanimate, but concerns human relations, it would seem that bias was peculiarly present, since much of the material with which we deal has highly emotional connotations. Many of our problems go back to questions of sex, of family, of religion, of industrial relations, of wealth distribution and of politics, and all these matters involve strong desires. The great difficulty here is the one of devising objective and, if possible, quantitative methods of observation and analysis, in order that we may accumulate the facts with which bias may be curbed.

The complexity of social phenomena is often mentioned as an obstacle to social fact-getting, but in reality complexity is a blanket term used to cover three special obstacles which are also present in physical sciences—obstacles that the physical scientist has overcome, or circumvented by many ingenious devices of observation. There is not time or space to elaborate this point beyond indicating that the three difficulties, *rarity, subtlety* and *fixity,* that occur in social phenomena, may be dealt with separately, as in the following illustrations:

Of *rarity,*[4] or infrequency of occurrence, says Jevons, "we might wait years or centuries to meet accidentally with facts which we can readily produce at any moment in the laboratories." In social science, we seek control of the economic factor, by minimum wage legislation, or we attempt to control the environment by placing the orphan child in a carefully supervised foster home.

Subtlety of social phenomena often makes them escape ordinary experience. According to Dewey, this quality may appear in the form of minuteness, or violence.[5] In social science, we have learned that the crowd psychology of a financial panic, the psychology of a political upheaval or the behavior of a mob are all merely extreme forms of pluralistic behavior and follow common principles of social psychology.

Rigidity of facts, as we ordinarily experience them in society, often suggest complexity. We see groups and social forms in a state of growth, others in a state of maturity or equilibrium, and others in a state of decay, and do not realize that every group or social form is not rigid, but tends to pass through a cycle of stages of growth, maturity and decay.

Ways in Which These Difficulties Have Been Partially Met and Overcome

There are three fairly well standardized methods of social research:[6] first, the *historical* method of critically using the records

[4] Dewey, "How We Think," pp. 91–93.

[5] *Op. cit.*

[6] Chapin, "Field Work and Social Research."

of past events; second, *field work,* or direct observations of contemporary social phenomena; third, the *statistical* method of quantitative measurement, classification and interpretation by aid of mathematics. Let us consider each method separately.

Social phenomena are continuous. We strive to understand the present and to predict the future by study of the past. The geologist finds in rocks the records of the past and paleontology is the study of fossil evidences of forms of life now extinct. The social scientist has no such direct and objective evidence of past phenomena. He must, consequently, resort to the observations of past events made by contemporary observers of them and recorded in historical documents.

Historians have developed a method of criticism of documentary evidence which should supplant the prevailing credulous acceptance of the written word. It is not possible in this short paper to describe the modern *historical method*[7] of documentary criticism, more than to say that it is a highly developed technique for evaluating in truly scientific fashion the records of observations made in the past by persons now deceased. By using this method, we may distinguish between the mere witness of a past event and the reliable observer of it. The social scientist can thus discriminate between fact and fancy and utilize the records of previous observations in a fashion that will make due allowance for the element of bias.

Field work in the social sciences consists of organized and systematic efforts to observe contemporary social phenomena. We may distinguish at least three variations in technique;[8] first, complete enumeration as of a government census of population; second, sampling, or the study of parts less than the whole, often illustrated by the survey method; and, third, case work investigation which supplies a technique for an intensive and many-sided study of the individual.

It is not necessary to describe the work and organization of census-taking[9] beyond stressing the point that a serious and scientific effort is made to obtain accurate and complete enumeration of some important economic, political and social attributes of our citizens. In view of the fact that thousands of untrained enumerators are used for this purpose, a surprising degree of accuracy and completeness of returns is secured by means of careful pre-planning, a detailed schedule, instruction of enumerators and supervision in the field.

7 Langlois and Seignobos, "Introduction to the Study of History."

8 Chapman, *op cit.* chs. 1, 3–8.

9 Decennial Census of the Commonwealth of Massachusetts, 1915, Part I, pp. 3–32.

The survey method is so familiar that it need not be elaborated in detail. The selection of a random sample less than the whole is often the scientific basis for such field work. In this connection, it is merely enough to call your attention to the fact that mathematical formulae are available to test the probable error of such samples. Beyond this, some interesting experiments have been made to perfect the schedule used by the field worker. The schedule is a mechanical instrument of observation and measurement used in social science to extend and standardize the observational powers of the senses. By use of schedules and score cards, it is sometimes possible to measure in quantitative terms social phenomena that ordinarily are described in purely qualitative terms. There is not time nor space to elaborate this point, but I wish to call your attention to various efforts which have been made to develop score cards for the study of the manner of living, housing conditions, neighborhoods and homes.[10] In so far as objective and quantitative terms of description are used in schedules, ordinary bias may be diminished

The technique of *case work investigation* has been developed by social workers engaged in philanthropic relief and social welfare activities. It is far too elaborate a technique to describe here, beyond saying that the beginnings of a real scientific technique for the study of the individual in his social relations is found in case work.[11] Case work investigation draws upon the historical method in its critical use of documentary sources of information about persons, it draws upon psychology and the science of law in its principles of interviewing clients and weighing and evaluating evidence. Case work investigation has probably done more than any other single influence to make modern relief-giving scientific and constructive.

It is hardly necessary to emphasize the scientific character of the *statistical method.* To save time, then, I shall assume that my readers are familiar with this method; but there are two illustrations of the use of the statistical method made within recent years in which, it seems to me, there exists great promise for overcoming some of the difficulties which stand in the way of using the experimental method in social science.[12] The first illustration that I have in mind is the use of the formula of partial or multiple correlation. By this device, it has been possible to measure the relative importance of different causative factors in a given situation.

[10] Chapin, *op. cit.*, ch. 7, especially pp. 176–185; and Whittier State School (Calif.) bulletins No. 8—"A guide to the grading of neighborhoods," and No. 9—"A guide to the grading of homes."

[11] Richmond, "Social Diagnosis."

[12] Chapin, "The experimental method and sociology," *Popular Science Monthly*, Vol. 4, Nos. 2 & 3, Feb., Mar. 1917; and "Elements of scientific method in sociology," *Amer. Jour. Sociology*, Vol. 20, No. 3, Nov. 1914.

Ogburn[13] has shown that the correlation of food expenditure per man per day with incomes is $r = +0.391$. When the partial correlation coefficient is computed with the size of the family constant, $r = +0.549$. The second illustration is the now familiar case of the business cycle. The studies of Mitchell,[14] Moore[15] and Persons[16] have shown that there are three superimposed fluctuations in a long time series representing certain kinds of economic phenomena. The indexes of prosperity and depression extending over a term of years show a long term trend or tendency to rise or fall; superimposed upon this is the cyclical swing of prosperity and depression; and superimposed on this cycle are seasonal fluctuations. This is a fairly good illustration of the complexity of social phenomena. By means of certain mathematical formulae, it is possible to measure each one of these types of change separately. These two illustrations suggest that the statistical method helps overcome some of the difficulties which stand in the way of a controlled observation of social phenomena.

Relation of These Methods of Social Research to the So-called Scientific Method

Peirce[17] claimed that science is confronted by three tasks: First, the discovery of laws of natural phenomena, performed by the inductive process; second, the discovery of causes, accomplished by hypothetic inference; and third, the prediction of effects, accomplished by use of deduction. If we accept this definition of the practical tasks of science, then the following chart will help us to see the orientation of methods of social research and scientific induction:

Tasks of science	*Scientific method*	*Methods of social research*
1. Discovery of laws by induction	1. Formulation of working hypothesis	(1) Historical method of critical examin. of documents
2. Discovery of causes by hypothetic inference	2. Collection of facts of observation	(2) Field work observation a—complete enumeration b—sampling c—case work
3. Prediction of effects by deduction	3. Classification of facts of observation	(3) Statistical method of interpretation
	4. Generalization from facts of observation	

13 "Analysis of the Standards of Living in the District of Columbia," Publ. Amer. Statistical Association, Vol. 16, N. S. No. 126, June 1919.

14 "Business Cycles," 1915, "Business Cycles and Unemployment," 1923.

15 "The laws of wages," 1913, "Economic cycles—their law and cause," 1914, "Generating economic cycles," 1923.

16 Review of Economic Statistics, by the Harvard Committee on Economic Research.

17 "A Theory of Probable Inference," Johns Hopkins University, *Studies in Logic*, 1883.

If the test of science is its power to predict future events, then the social sciences are deplorably weak on this test. The chief reason for this weakness in prediction is that social sciences are in a theoretical and speculative stage of development because their laws are empirical laws at best, and not scientific laws. It has already been pointed out that scientific induction is the only foundation upon which a generalization can rest, if that generalization is to be used with assurance as a basis of prediction At the present time social sciences have inadequate facts for induction and students tend to be more interested in speculation than in observation.

But there is another larger aspect of the failure of social science to develop generalizations from which valid predictions can be made, and the failure to supply a practical applied social science.

It seems to be true that a certain general cultural threshold must be passed before certain other cultural advances can come. In applied science, the practical aeroplane could not have been developed until a light unit for motive power had been invented, *e g.*, the internal combustion engine, and this in turn could not be developed until chemistry and electrodynamics had reached a certain stage. The great newspaper machine presses of to-day are not to any great extent the result of an empirical trial and error process, but are derived from inventions based upon scientific discoveries.

Bernard[18] contends that inventions in the field of the physical sciences, applied to economic and industrial activities, have passed very largely out of an empirical stage and are now in the stage of projected invention. In projected invention a vast number of mathematical or mechanical formulae are prepared and reduced to logical order on paper. These formulae are often visualized by transfer to blue prints; finally, the machine is constructed to correspond to the blue print. In the field of chemistry we find examples of projected inventions made on the basis of antecedent method inventions in chemistry and mathematics. This would be true of such discoveries as TNT, the high explosive, as well as of synthetic rubber Thus, in modern machine manufacture and in the production of textiles, foodstuffs and many other manufactured articles of commerce, the laboratory sciences of chemistry, physics and their affiliated sciences are in a scientific stage of development of what has been called projected inventions. By contrast, in social relations we fail in statecraft, in political activity, in organization of industrial relations and in the care of dependent, defective and delinquent classes chiefly for the reason that the sciences basic to any scientific treatment of these problems are still in an empirical

[18] "Invention and social progress," *Amer. Jour. of Sociology*, Vol. 29, No. 1, July, 1923, pp. 1–33.

and a speculative stage of discovery and invention. The social studies can not pass from this empirical stage and attain the truly scientific stage until they use the inductive method more generally as a necessary preliminary to deduction and prediction.

ORGANIZED EFFORTS TO STUDY SOCIAL PHENOMENA IN A SCIENTIFIC MANNER

In general, it may be said that in our universities that possess strong graduate departments of economics, political science and sociology, real scientific research is being carried on. The historical method, careful field work studies and statistical interpretation are widely used in these university departments.

When it comes to describing the work of typical research agencies outside of our universities, one finds the field of bewildering complexity. I shall, therefore, merely mention a few illustrations of organized efforts to conduct social research in accordance with scientific principles.

In the field of political science there is a large number of privately or publicly supported bureaus of municipal research, institutes of public service, or legislative municipal reference bureaus. In this connection I wish to call your attention to the recent report of the committee on political research of the American Political Science Association.[19] In this report you will find a description of research activities in the field of politics.

At the present time a considerable number of privately endowed bureaus and foundations for economic and industrial research exist. These bureaus vary in organization and in the range of subjects studied. Some are undoubtedly more interested in pure science, while others are more interested in immediate and profitable application of the findings of economic research to pressing commercial and industrial problems. The American Economic Association has a joint committee with the American Statistical Association, advisory to the Federal Census. This committee has done notable work in suggesting to the officials of the Federal Census improvements in the technique of gathering information and of its interpretation. The American Economic Association has also had a committee on terminology, which indicates that there is an active interest in standardizing terms in accordance with better scientific practice.

In the sociological field investigations have been carried on by national foundations such as the Russell Sage Foundation, the Carnegie Corporation, the Commonwealth Fund and others. The

[19] "Progress report of the committee on political research," *Amer. Pol. Sci. Review*, Vol. 17, No. 2, May 1923, pp. 274–312.

American Sociological Society has a standing committee on social research and a standing committee on social abstracts.[20] Among the scientific workers in the applied and practical fields of sociology, there should be mentioned the various committees on terminology of the American Association of Social Workers.

No treatment of this subject would be complete without mentioning the fact that a National Social Science Research Council was organized in the spring of 1923. This council is composed of delegates from the four following social science associations: The American Economic Association, the American Political Science Association, the American Statistical Association and the American Sociological Society. This organization is at present engaged in planning a survey of the entire field of social research in the United States. It is also considering the possibility of organizing a social science abstract service which will make accessible to scholars and research workers in the field of the social sciences the vast amount of periodical literature on social science now almost inaccessible because of its overwhelming volume.

[20] See annual reports of these committees in the Proceedings of the Amer. Sociological Society for 1920, 1921, 1922 and 1923.

THE ASTRONOMY OF SHAKESPEARE

By JOHN CANDEE DEAN

SHAKESPEARE'S position in relation to earlier English literature was similar to that of the great Greek sculptors in respect to their earlier art. His writings abound in conceptions of life, wherein he displays exquisite skill in depicting mankind in perfect harmony with nature. While he is said to have possessed but little knowledge of Latin, and less of Greek, he appears to have been well informed in current philosophy and science of the Elizabethan period, so much so that his plays are sometimes said to have been written by the greatest philosopher and scientist of his time, the so-called father of inductive reasoning.

Shakespeare's writings teem with references to astronomy, and it may be of interest to examine into his conceptions of that science. For ages the superstitions of astrology had ruled the people of the world, and in the sixteenth century they had lost little of their power. Although Elizabeth had strong common sense, and was something of an agnostic, she had her astrologer, and sometimes followed his advice in important matters. In 1580 she issued an order of prayer to avert God's wrath, in which she referred to eclipses, comets and even heavy falls of snow as evidence of His great displeasure.

Shakespeare was born 21 years after the death of Copernicus, yet there is nothing in his writings to indicate that he ever heard of the Copernican theory. All his references to astronomy are based on the old geocentric theory. Galileo was born in the same year that Shakespeare was. He invented his telescope and discovered the system of Jupiter's planets when he was 45 years old, yet there are no references to Galileo in Shakespeare's works. However, we must not be astonished at this apparent ignorance; it took 200 years to establish the Copernican theory in the minds of even educated people.

Shakespeare was really quite advanced in the philosophy of his time. He did not believe in astrology, when nearly the whole world did. He disclaims this belief in his Sonnet XIV, where he says:

> Not from the stars do I my judgment pluck;
> And yet methinks I have astronomy,
> But not to tell of good or evil luck,
> Of plagues, of dearths, or seasons' quality.

While he knew astronomy, he did not employ it to predict the weather, luck, or death, etc.

In "King Lear," Edmund rails at astrology.

> When we are sick in fortune, we make guilty of our disasters, the sun, moon and stars, as if we were villains on necessity, fools by heavenly compulsion. Knaves, thieves and treachers by spherical predominance, drunkards and liars by enforced obedience to planetary influence; and all that we are evil in, by a divine thrusting on.

This reads like an expression of Shakespeare's real contempt for this pseudo-science. He depicts Roman superstitions in "Julius Caesar," where Calphurnia warns Caesar of his danger through premonitory signs:

> A lioness hath whelped in the streets,
> And graves have yawned and yielded up their dead.
>
> Horses do neigh, and dying men did groan,
> And ghosts did shriek and squeal about the streets.
>
> When beggars die there are no comets seen,
> The heavens themselves blaze forth the death of princes

Caesar's reply to this is worthy of him:

> Cowards die many times before their deaths,
> The valiant never taste of death but once.

It is a most singular coincidence that a brilliant comet did appear three months after Julius Caesar's death, when Rome was in a turmoil. The comet was supposed to be Caesar's metamorphosed soul armed with fire and vengeance. In his beautiful painting "The Ides of March," E. J. Poynter, P. R. A., shows Calphurnia pointing out to Caesar the alarming apparitions in the evening sky, in which a comet is shown, but the painter had antedated its appearance by three months.

Just before his death, Caesar had compared his constancy with that of Polaris:

> I am as constant as the northern star
> Of whose true-fix'd and resting quality
> There is no fellow in the firmament.
> The skies are painted with unnumbered sparks,
> They are all fire, and everyone doth shine,
> But there's but one in all doth hold his place.

In "Hamlet," Horatio describes the strange phenomena of the heavens over Caesar's death:

A little ere the mightiest Julius fell,
The graves stood tenantless and the sheeted dead
Did squeak and gibber in the Roman streets,
As stars with trains of fire and dews of blood,
Disasters in the sun, and the moist star,
Upon whose influence Neptune's empire stands
Was sick almost to doomsday with eclipse.

The "moist star" is the moon which causes the tides and was supposed to control the weather by bringing rain. This superstition of the moon's influence on the weather still strongly persists, but carefully recorded observations, covering many years, at Greenwich Observatory prove that there are no relations between the moon's changes and the weather.

In "The Tempest," Miranda asks her father why he has brought on the tempest. Prospero replies:

Now my dear lady, hath mine enemies been
Brought to this shore, and by my prescience
I find my zenith doth depend upon
A most auspicious star; whose influence
If now I court not, but omit, my fortunes
Will ever after droop—Here cease more questions.

We thus see that Prospero's "auspicious star" has been courted to assist in bringing his enemies to his magic island.

In "Romeo and Juliet," Juliet says:

Yon light is not day-light, I know it.
It is some meteor that the sun exhales
To be to thee this night a torch-bearer.

The idea that meteors have come from the sun is not inconsistent with the recent planetesimal hypothesis.

Copernicus published his great work, "The Revolution of the Heavenly Bodies," 21 years before Shakespeare was born. A few men of learning read it, the church rejected it, and it received but little attention until the time of Galileo, who was born the same year that Shakespeare was. The church saw new dangers in the discoveries of Galileo, and used its great powers to overthrow them. Galileo was accused of heresy and atheism, and was imprisoned. He lived to see his works expelled from all the universities of Europe and their publication prohibited.

The latter part of the sixteenth century was a period of great longings for knowledge by the educated class. Christopher Marlowe, poet, dramatist and friend of Shakespeare, in his play of "Tamburlaine," beautifully expresses the higher human aspirations of this period:

> Nature that formed us of four elements,
> Warring within our breasts for regiment,
> Doth teach us all to have aspiring minds;
> Our souls, whose faculties can comprehend,
> The wondrous architecture of the world,
> And measure every wandering planet's course,
> Still climbing after knowledge infinite.
> And always moving as the restless spheres,
> Will us to wear ourselves, and never rest,
> Until we reach the ripest fruit of all.

The average man loves superstition, loves and fears the supernatural, and is fascinated by the incomprehensible. Idle fancies are still cherished that the mind and body are affected by the light of the moon, that its rays sometimes produce blindness by shining on the sleeper's eyes, that death occurs at the time of the change of tide, and that insanity is produced by the moon's influence. When Emilia discovers that Desdemona has been murdered, she calls to Othello, "Oh, my good lord, younder's foul murther's done." Othello replies:

> It is the very error of the moon;
> She comes more near the earth than she was wont,
> And makes men mad.

In other words the moon was in perigee, the most dangerous point in its orbit, and under its influence he had committed the murder while temporarily insane.

Astrology taught that eclipses expressed the distress of nature over terrestrial calamities, while comets portended greater woes than all the other celestial signs combined. Luther declared them to be the work of the devil and called them "harlot stars." Even Milton says that the comet "from its horrid hair shakes pestilence and war." Whole nations from the king down to the lowest peasant were frequently plunged into the direst alarm by the appearance of these messengers of misery.

Lord Francis Bacon, lawyer, philosopher and scientist, probably never met Shakespeare. Each was doubtless unconscious of the other's genius. The difference in rank, at that time, was sufficient to prevent their meeting. Bacon evidently never read Shakespeare's poetry, never went to see his plays and did not seek the author. In his "Advancement of Learning," Bacon wrote nobly of the poet's art, but nowhere does he exhibit any knowledge of Shakespeare's plays, which 300 years later were thought by many to be so great that none but Bacon could have written them. Bacon's talents have been overestimated by literary men who had little idea how scientific discoveries are made. He was ignorant

of higher mathematics and thought them useless in scientific investigations. He made many mistakes, the greatest of which was that of rejecting the Copernican system of astronomy, and went to his grave believing that the earth was the center of the whole universe. The illustrious Newton never acknowledged that he was under any obligation to Bacon Newton knew that nature always works by geometry, and achieved his great discoveries through mathematics. There seems to be little evidence that Bacon could have written the plays of Shakespeare.

Some of us still remember Henry Irving's lovely moonlight scene in Portia's garden at Belmont where Lorenzo and Jessica were awaiting the return of Portia from the trial of the merchant Antonio. One of the most beautiful passages in Shakespeare is presented when Lorenzo, after requesting that the musicians be brought into the open air, says.

> How sweet the moonlight sleeps upon this bank!
> Here will we sit and let the sounds of music
> Creep in our ears; soft stillness, and the night
> Become the touches of sweet harmony.
> Sit, Jessica. Look, how the floor of heaven
> Is thick inlaid with patines of bright gold.
> There is not the smallest orb which thou beholdest,
> But in his motion like an angel sings,
> Still quiring to the young-eyed cherubims:
> Such harmony is in immortal souls;
> But while this muddy vesture of decay
> Doth grossly close it in, we can not hear it.

Here with delicate beauty the Greek theory of the universe is set forth. The idea of a spherical universe was a very natural one. It was believed that the planets and stars were set in a series of concentric spheres, each so perfectly transparent that bodies in the more distant ones were visible through all the intervening ones. Each planet had a separate sphere.

In Italy the stars burn with a piercing brilliancy. The planets are wonderfully radiant. While on Lake Maggiore on clear summer nights, the writer witnessed a brightness of the stars, planets, the galaxy, and of the zodiacal light, unequalled in the Mississippi valley.

Milton in his "Arcades" parallels Shakespeare's lines, but in beauty, sentiment and harmony, it will be seen that he falls below the great master:

In deep of night when drowsiness
Hath lock'd up mortal sense, then listen I
To the celestial Siren's harmony,
That sits upon the nine infolded spheres.
Such sweet compulsion doth in music lie,
To lull the daughter of Necessity
And keep unsteady Nature to her law,
And the low world in measured motion draw
After the heavenly tune which none can hear
Of human mould, with gross unpurged ear

Dante in his "Paradise" describes the crystal orbs as being rotated by angels.

The virtue and the motion of the sacred orbs,
As mallets by the workman's hand must needs
By blessed moovers be inspired.

While Shakespeare was writing his plays Giordano Bruno visited England, where he resided for a time. He delivered lectures at Oxford University on the astronomy of Copernicus and published his exposition of the Copernican system.

From the second century to the beginning of the fifteenth century, a period of 1,300 years, the theory of astronomy had remained unchanged. The divine music of the revolving spheres could be heard only by angels and immortals. According to Ptolemy, the abode of the blessed was outside of the sphere of the fixed stars. In 1607 the world was thrown into consternation by the appearance of Halley's comet. Kepler, royal astronomer at Prague, and discoverer of the laws of planetary motion, quietly traced its course and found that it came from outside of the moon's orbit. This announcement caused a great outcry because it assailed the dogma of the crystalline spheres. The course of a super-lunar comet would send it crashing through the spheres. Kepler was abused, imprisoned and warned that he must bring his theories into harmony with the scriptures.

In 1607, when Halley's comet appeared, Shakespeare was still occupied as actor, manager and writer of stage plays. This brilliant comet probably caused more consternation than any other within historic times. Shakespeare was, therefore, a witness of the alarm of the world over the appearance of this dire messenger of woe, when the churches filled with terror-stricken multitudes.

The following lines are from "Troilus and Cressida":

The heavens themselves, the planets, and this center,
Observe degree, priority, and place,
Insisture, course, proportion, season, form,
Office, and custom, in all lines of order.

Shakespeare here exhibits a true sense of the orderly invariability of nature's laws, as announced about forty years after his death by the French philosopher Descartes, who was the first to declare nature's laws to be unchangeable. By "this center," the poet, of course, refers to the earth. Here the geocentric hypothesis of Ptolemy reappears.

In "Measure for Measure," there is a single line of the highest poetical quality which brings up a mental picture of the approaching dawn.

"Look, the unfolding star calls up the shepherd.". The "unfolding star" is Venus, which appears over the eastern hills at early dawn, and calls the shepherd to release the flock from the fold while the grass is still wet with morning dew.

THE PHYSICAL BASIS OF DISEASE

III. TISSUE DEGENERATION

By THE RESEARCH WORKER
STANFORD UNIVERSITY

"Our Boston acquaintance seems to have taken offense," said the lawyer, as he welcomed the manufacturer and the research worker to his compartment the next morning.

"He said he didn't care to listen to any more heresies," said the manufacturer.

"I fear I was not successful in differentiating between the field of formal biological science and that of religious speculation and belief," replied the research worker. "Formal biology is concerned solely with material facts. Religion deals essentially with facts beyond the reach of material science. I see no reason why the two fields should ever be in conflict. My own religious beliefs or disbeliefs are not based on material facts. They haven't been altered, so far as I can see, by my formal scientific training."

"Aren't all biologists atheists?" asked the lawyer.

"There is as wide diversity of religious belief among biologists as among people of the same grade of intelligence in other walks of life."

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"As our third group of diseases," continued the research worker, "I have selected diseases due to degenerative changes in important organs or parts. Such degenerations may affect any organ or tissue of the body. One of the best examples of such degenerations is the change in muscles and bones in infantile paralysis. We have seen that the essential or fundamental injury in infantile paralysis is death of certain portions of the gray matter of the spinal cord. As a result of this nerve cell death, certain muscles can no longer be used. Prolonged disuse of these muscles leads to their degeneration and decrease in size. The muscles or portions of muscles affected are eventually reduced to flabby strands but a fraction of their original size. Microscopic examination shows the contractile fibers in these muscles markedly shrunken, atypical in structure, and decreased in number, the main body of the muscle being composed of inert scar tissue.

"One of the distressing effects of this muscular degeneration is the production of unsightly deformities of the bones. Such

degenerations usually destroy the mechanical balance between antagonistic muscle groups, so that the bones are constantly being drawn toward an abnormal position. The bones are gradually distorted by this new pressure relationship.''

''I shouldn't think changes in pressure would alter the shape of bones,'' said the manufacturer.

''The bones are not inert structures. Look at any bone with a magnifying glass and you will see innumerable small openings or pores. These are passages for minute blood vessels and accompanying structures. At certain points the solid bone is being constantly eroded and absorbed by these structures. The bone is being constantly strengthened or built up at other points. The entire skeleton is virtually torn down and rebuilt by this method several times during average adult life This tearing down and rebuilding of bone is governed largely by pressure relationships. Altered pressure relationships cause the bones to be rebuilt in atypical shapes.''

''Degenerations of the same type may take place in internal muscular structures of the body. They are fairly common, for example, in the heart. In elderly individuals or in young individuals as the result of the action of toxic or infectious agents, the walls of the heart become flabby and may be reduced to but a fraction of their normal thickness. In certain cases, little or no change in the thickness of the heart walls takes place, but on microscopic examination the muscle fibers are found shrunken, atypical in structure and reduced in number. The walls of such hearts are composed largely of inert scar tissue. The available strength of a degenerate heart is less than normal While a normal heart rarely uses more than 10 per cent of its available strength to maintain normal circulation, the degenerate heart may require half or even its entire available strength. Its reserve capacity or factor of safety is very small.''

''Degenerate hearts are not only weaker than normal, but may show marked changes in the nature of their contractions. With severer degenerations the contractions are often delayed or sluggish, reducing the heart rate. With milder degenerations, the heart muscle may be unusually irritable, contractions occurring at much greater frequency than normal. Irregularities in the rate and in the strength of the contractions often occur. Coordination of different portions of the heart muscle may be interfered with. Different chambers of the heart, for example, may beat at different rates. One chamber of the heart may contract at such a time

as to prevent its normal filling with blood from the preceding chamber. Such a heart uses up a large part of its available strength in useless work. In extreme cases, complete incoordination of various portions of the heart muscle takes place. The muscle shows irregular independent twitchings, jerkings and worm-like movements of its different parts. Orderly contractions are no longer possible "

"I should think that would kill a person immediately," said the manufacturer

"That depends upon the portion of the heart affected. The auricles, for example, may be completely paralyzed by this method, and enough blood be forced or sucked through them to maintain life."

"Is that what is known as palpitation of the heart?" asked the lawyer.

"Palpitation of the heart is a term usually applied to any abnormal consciousness of heart action. This may be due to abnormal heart action. It is often, however, a purely psychological phenomenon due to heightened consciousness of heart action. I should prefer to postpone discussion of this topic till we take up diseases due to psychical factors.

"Muscular degenerations are also found in the blood vessels. We have seen that the artery walls are composed of muscle fibers and supporting tissues The muscle fibers usually decrease in size and in number in advanced life. They may become degenerate in early life as a result of toxic and infectious agents. The artery walls may be virtually reduced to inert scar tissue. Degenerate arteries are weaker than normal, and show an increased tendency to rupture. They are also relatively inelastic. They tend to remain expanded to their maximum diameter, even with low blood pressure. One of the effects of this loss of elasticity is to increase the amount of work necessary to maintain normal circulation. Greater force is required to force blood through the inelastic arteries, than through the normal rubber-like blood vessels."

"Serious circulatory disturbances may also result from degenerations in the blood itself. The blood, as you know, is a nearly colorless fluid in which are suspended numerous minute cells, the red blood corpuscles. These corpuscles are of uniform size, uniform shape and of uniform color. Blood degenerations may show themselves by a reduction of the number of these red blood corpuscles, by irregularities in their size, irregularities in shape or irregu-

larities in color. The blood, for example, may contain but half of the normal number of red blood corpuscles per unit volume. Many of these corpuscles may be deformed and but half their normal size. They may contain little or no red coloring matter. The red blood corpuscles, as you know, are the oxygen-carrying mechanisms of the blood. They take up oxygen in the lungs, and give off oxygen where needed in the internal organs."

"They're intelligent," said the manufacturer. "Loading up with oxygen in the lungs, and dumping oxygen where needed in the body. Clever work."

"So far as we know, no intelligence enters into this process. The action of the corpuscles is due solely to the chemical properties of the red coloring matter they contain. This coloring matter outside the body absorbs oxygen from the air, and gives off oxygen if the amount of oxygen in the surrounding medium is sufficiently reduced. Many other chemical substances will act in the same way."

"Our Boston acquaintance would call this atheism," said the lawyer.

"There is no suggestion of atheism in it. Biologists have simply explained one of the mechanisms by means of which the mysterious life force operates. They offer no explanation as to the nature of this life force.

"Blood degenerations usually reduce the oxygen-carrying capacity of the blood. This is due to a reduction in the amount of red coloring matter. There is normally a very generous factor of safety in oxygen-carrying capacity. Blood usually carries three times the amount of oxygen needed by internal organs. The red coloring matter of the blood may be reduced to a quarter of the normal amount, and still be able to supply all ordinary tissue needs. One of the ways in which the blood is assisted in doing this is by an increase in the rate of blood flow. The blood is thus used more frequently than normal to transport oxygen to the tissues. This increased blood flow of course throws an additional burden on the heart."

"Equally striking degenerations take place in the respiratory system. A good example is the collapse of a portion of the lungs following occlusion of a bronchus. If a bronchus is plugged by a foreign object or by exudate, or is closed by swelling of the bronchial walls, or by outside pressure, the portion of the lungs supplied by this bronchus is cut off from its external air supply. The air contained in this portion of the lungs is gradually absorbed.

This portion is eventually reduced to a shriveled, airless mass of solid tissue. Blood passing through this portion of the lungs is of course no longer supplied with oxygen.

"A second example of respiratory degeneration is cavity formation from bronchial dilatation. Degenerative changes in the bronchial walls may so weaken these walls as to lead to their gradual inflation. In extreme cases, immense cavities may be formed by this method A whole lobe of the lungs may be changed to an open cavity, surrounded by collapsed or semi-collapsed lung tissue. Blood passing through this portion of the lungs is incompletely aerated.

"Degenerations may also take place in the air sacs. The walls of these air sacs become weaker than normal, and lose their elasticity. Neighboring air sacs may rupture into each other, forming minute cavities. The individual air sacs are often permanently dilated to many times their normal diameter. A lung that is covered with hundreds of bladder-like cavities is not unusual The ventilation of these cavities is usually defective. The blood is inadequately aerated. On account of the generous reserve oxygen-capacity of the blood, incomplete aeration is usually not a serious matter. It reduces one of the important factors of safety, however, in all organs and tissues"

"I don't see what a physician can do to cure such cases," said the manufacturer.

"I should prefer to postpone discussion of treatment till we have completed our review of the different types of disease. In some cases almost miraculous cures can be effected. In many cases, readjustments of the mode of life may be made that will allow the person to live comfortably with his reduced factors of safety."

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"Very striking degenerations are found in the digestive tract. The stomach lining, for example, may be shriveled to but a fraction of its normal thickness. This lining, as you know, contains the glands that secrete gastric juice. With such degenerations, the amount of gastric juice is usually reduced. Its chemical nature is often altered. The digestive processes are usually atypical. Putrefaction of food may take place.

"Equally striking degenerations may take place in the muscle fibers of the stomach walls. These may be markedly shrunken, atypical in structure, or decreased in number. In extreme cases the walls may be reduced to inert scar tissue. Muscular degenerations reduce the power of the stomach to cause proper movement of food. Stagnation and putrefaction of food may result.

"Probably the most striking examples of degeneration in the digestive system take place in the liver. The liver, as you know, is not only a digestive organ, but is one of the main blood-purifying organs of the body. Blood circulating through the walls of the intestines, for example, is purified by the liver before being returned to the general circulation. Bacteria and toxic substances are absorbed or filtered out.

"Microscopically the liver is seen to be composed of special liver cells, held in place by supporting tissues, and richly supplied with blood vessels. Marked degenerations may be produced in the liver cells as a result of the action of toxic or infectious agents. The cells are shrunken, atypical in structure, and diminished in number. The whole liver may thus be reduced to a fraction of its normal size. Often, however, the size of the liver is not reduced, the shrunken liver cells being replaced by scar tissue. The liver may even be increased by this scar tissue growth to two or three times its normal size.

"Degenerations usually reduce the detoxicating powers of the liver. The liver, however, has a very generous reserve capacity, so that it does not become incompetent for the normal needs of the body till nearly two thirds of the liver cells are thrown out of function. Excessive amounts of scar tissue in the liver, however, may produce serious mechanical effects, even though the liver is otherwise competent. The scar tissue usually increases the resistance to blood flow through the liver. Blood is mechanically dammed back into the stomach and intestines, causing marked engorgement of these organs With prolonged engorgement there is often a constant outward leakage of the blood plasm into the abdominal cavity. Many quarts of fluid may thus accumulate."

"An incurable condition," said the manufacturer.

"Not necessarily. Small veins passing upwards along the esophagus, for example, may gradually enlarge so as to effectively drain off the excessive blood from the stomach and intestines.

"Another striking degenerative process in the liver is the formation of gelatinous deposits. In certain chronic diseases, chemical alterations are produced in the blood and body fluids, sufficient to cause gelatinous material to be precipitated or deposited in tissue spaces. These gelatinous deposits may be so marked in the liver, for example, as to surround and kill the liver cells. Large portions of the liver may be thus replaced by firm gelatinous masses, resembling soft rubber. This gelatinous material has some of the properties of stiff starch paste."

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"Degenerations are equally common in the nervous system. This, of course, is a normal process in advanced age. In younger individuals nerve cell degenerations may be produced as a result of the local action of toxic agents or of disease-producing microorganisms Degenerations follow local circulatory disturbances. In experimental animals, nerve cell degenerations may be produced by prolonged loss of sleep, excessive muscular activity or emotional excitement In certain individuals, nerve cell degenerations take place without assignable external cause. Statistics show that they are usually the result of defective hereditary endowment

"Degeneration of the nerve cells may be general throughout the nervous system, or it may be confined to certain areas or structures of the brain or spinal cord Microscopically the nerve cells may be shrunken, distorted, may contain cavities or vacuoles or may be filled with granular deposits The nerve fibers connecting the cells may be shrunken, fractured or even absent. The space originally occupied by the nerve cells may be filled with fluid or occupied by scar tissue.

"The effects of degenerations upon the activity of the nerve cells depend upon the type and degree of degeneration Pronounced degeneration usually reduces the activity of the nerve cells. Severely degenerated portions of the brain or spinal cord respond only to unusually strong stimuli. In extreme cases the reacting power is completely lost. Milder degenerations may actually increase nerve cell activity. Such cells respond with explosive violence to stimuli that would not affect a normal cell. They may even be thrown into explosive activity with no demonstrable external cause.

"The resulting symptoms depend upon the number and location of the nerve cells affected. With severer degenerations the symptoms approach those of death of nerve cells, which we have already considered. There may be partial loss of the power to receive or recognize sensations, reduction in the power to initiate or coordinate muscular movements, and reduced power to inhibit instinctive actions.

"With less severe degeneration, there may be heightened nerve activity. A gentle touch on the skin, for example, may be felt as unbearable pain; the ticking of a watch may be heard as pistol shots; ordinary desire for food may be felt as wolf-like hunger. Sensations may even arise with no demonstrable external cause. The ticklings, tinglings, sense of pressure, and shooting pains, which are often experienced in early syphilitic degenerations of the spinal cord, are good examples. Visual hallucinations may

result, false auditory sensations, delusions of muscular movements, fictitious feelings of disturbed equilibrium.

"Milder degeneration may also produce marked changes in muscular activity. In the early nerve cell degenerations of tetanus, for example, a gentle touch on the skin may throw all muscles of the body into such prolonged explosive contractions that death may result. Uncontrollable twitchings, jerkings or prolonged muscular contractions may take place, with no demonstrable external cause. Uncontrollable complex instinctive actions

"The usual general effects of nerve cell degenerations are reduced mental capacity, and altered personality and character. Marked degenerations give the various types of feeble-mindedness, dementia and insanity."

"It is a wise provision of law not to hold these persons legally responsible," said the lawyer.

"Individuals with sufficiently marked nerve cell degenerations to cause them to be classed as feeble-minded or insane are not held legally or morally responsible How about individuals with milder degenerations? Should they be held responsible?"

"The line must be drawn somewhere," said the lawyer.

"Might not our charitable point of view be broadened to include these individuals?"

"The nervous system has low factors of safety when compared with other organs. There is far less reserve capacity than in the heart and liver, for example Powers of regeneration are almost absent. Recovery is possible with the milder types of degeneration. Severe degenerations once produced are usually permanent."

"How about prevention?" asked the lawyer.

"One of the main causes of nerve cell degeneration is venereal disease. Visit almost any of our state institutions for the feeble-minded or insane. You will find a quarter to a half of the inmates, and sometimes more than a half, with nerve cell degenerations due to acquired or congenital syphilis. As a purely business proposition, it would pay any state to spend a million dollars a year to stamp out this disease.

"A serious difficulty in prevention arises from the large hereditary factors in nerve cell degenerations, individuals who develop senile changes in the nervous system either in childhood or in early adult life, without assignable or adequate outside cause. There are probably at least two million individuals in the United States at present whose descendants, even under the best hygienic and industrial conditions, will almost invariably develop nerve cell degenerations."

A JOURNEY IN SIBERIA

By Professor T. D. A. COCKERELL

UNIVERSITY OF COLORADO

It all came about through the discovery, by Mr. A. Kuznetzoff, working for the Vladivostok Museum, of two remarkable fossil insects on the Kudia River. These fossils, together with plant remains from the same locality, were referred to Dr. A. N. Kryshtofovich for investigation. He published an account of the plants[1] and sent the insects to the U. S. National Museum, whence they were transmitted to me. They proved to represent new genera of Panorpidae and Delphacidae, members of a hitherto unknown Tertiary fauna. Mrs. Cockerell at once proposed an expedition to Siberia to investigate the locality, but I did not believe such a thing possible. A friend in Washington advised us that the "Reds" were in control and it would be out of the question to visit the country. In the meantime, however, Mrs. Cockerell had written to Dr. Kryshtofovich, who at once replied in enthusiastic terms. At the request of the Geological Committee, the "Supreme Administrative organ of the Far East of Russia" gave permission for us to enter the country for the purpose stated. We secured a passport from Washington, but as our government does not recognize the Russian republic, it was impossible to get a visa in the United States. The same difficulty existed in Japan, so that we were obliged to proceed without an official visa, though we carried a letter from Mr. Boris E. Skvirsky, the unofficial representative of Russia in Washington. Optimistically assuming that everything would be all right, we crossed Japan to the port of Tsuruga, where the "Hozan Maru," with steam up, was waiting to carry us across the Japan Sea. Here we were unexpectedly halted by the local steamship office, the officials making various excuses for refusing to allow us to proceed. Much later we were told that they suspected that we were Russians trying to get into the country to create trouble, and feared the penalties which might be imposed by the "Red" government. The result was that we spent an extremely interesting and profitable week in Tsuruga, so that the delay eventually caused us no regret. Thanks to the activities of our friends in Yokohoma and Vladivostok, by the end of the week the Osaka Shosen Kaisha people were in a very amiable frame of mind, and gave us the best cabin on the boat. We had

[1] Records of the Geological Committee of the Russian Far East No. 15 (1921).

good weather across the Japan Sea, but when we approached Vladivostok we ran into dense fog and were obliged to wait for about twenty-four hours before proceeding into the narrow and tortuous channel leading to the city. We were in shallow water, and the captain and crew interested themselves in fishing with lines, catching great numbers of flounders, apparently of the species *Paralichthys olivaceus* (Schlegel), originally described from Nagasaki Dragonflies flew about the ship—our first sight of the insect-fauna of Siberia.

When we eventually arrived at Vladivostok, Dr. Kryshtofovich met us at the wharf, and we had no difficulty whatever with the officials, although next day the customs officials considered it necessary to make a catalogue of the entire contents of our two boxes. A little later we called on the Governor of the Maritime Province, who made a very courteous speech welcoming us, and provided us with a "mandate," signed with communistic red ink, requiring every one to give us prompt service and aid us in our scientific work. This document, representing the highest authority in that part of the country, smoothed our path on numerous occasions. This is not the place to discuss the Russian political organization or to enumerate the merits and faults of the Soviet government, but it will not be amiss to allude to those conditions which directly affect science and education. It is the policy of the government to extend and develop the educational system until every Russian has at least a common school education. This is a gigantic task, requiring funds and teachers not yet in sight, but it is the necessary step in developing any kind of functional democracy. It has often happened that educational programs have existed only on paper, lacking the popular interest and support to give them reality. We had ocular evidence that in Vladivostok, at least, the public was really aroused. When we arrived, they were having a school exhibit of the type commonly seen in America, except that one noticed the added feature of red flags, busts of noted communists and posters representing communistic propaganda. We reached the building about twenty minutes before the doors opened, and, although it was by no means the first day of the exhibit, the sidewalk and street were crowded with people, as if the place were some popular theater or other place of entertainment. Once inside, we found it necessary to almost push our way through the crowds. At certain points, copy-books were provided, and the visitors were invited to express their opinion of what they saw. The superintendent of schools in Vladivostok, we were informed, was an enthusiastic disciple of Professor John Dewey.

There were, of course, occasions for criticism. Some vigorously objected to communistic propaganda in the schools, but to the

"Reds" this has exactly the same significance as "Americanization" in our schools. It represents an effort to make a United Russia, on lines which the authorities consider necessary and desirable. It can not be said, however, that the "Reds" have it all their own way; the strict communists are in the minority, and are criticized without reserve by the rest of the population. Nevertheless, the general opinion is, I think even in communistic circles, that evolution and adaptation constitute the program for the future, and many able men who do not profess to be communists are glad to serve under the present administration, helping to build up a greater and better Russia. Thus we found technical experts, not at all identified with revolutionary activities, carrying on their work in public offices and receiving relatively high salaries. Such were Davidoff of the Hydrographical Institute, Solovieff and Kraloff of the Natural History Museum, Vladimirsky of the Meteorological Bureau, and our friend Kryshtofovich of the Geological Committee. Davidoff had served continuously since the days of the czar, and I saw in his office the proof-sheets of the new coast "pilot," which will total about 1500 pages, as against the 150 pages of the edition of 1907. This work is of the highest value, as it minutely describes and illustrates the features of the very rocky and dangerous Siberian coast, maps of which had been quite unreliable. Unfortunately, the work of surveying has been interrupted, because the "Whites," when forced to leave Siberia in 1922, carried off the only surveying vessel. I also saw in the hydrographical office large collections of marine animals, which will be transmitted to Russian specialists for study. At the meteorological office I saw an instrument, made in 1921 at Vladivostok under Vladimirsky's direction, which automatically registers the direction and strength of the wind every minute of the day. The Natural History Museum is an excellent institution, containing a very good exhibit of the native products of the Maritime Province and Amur country and a large library. It does its work on a minimum of income, and could hardly continue successfully were it not for the rent it derives from a moving-picture theatre next door. In the collection of stuffed animals, we saw the famous Ussuri tiger represented only by a cub; "the Museum is at present too poor to obtain a full-grown animal." There is a named collection of the Lepidoptera of the district, but other insects are lacking, having been sent away to European Russia, where they can be studied. Officially, the museum is under the auspices of the Geographical Society of Russia, but practically it is an independent institution.

The Commercial School, under M. Lutzenko, is a remarkable institution, with a wider scope than the name would suggest. The

library contains 25,000 books, including many valuable scientific works, such as Komarov's "Flora Manshuriae." The department of biology has a good collection, many of the specimens obtained by pupils. A picture of Darwin hangs on the wall. When the Communists came in, there was some question of distributing the materials in the Commercial School, on the ground that other centers were entitled to the same advantages, or all should share whatever was available. It was, however, clearly desirable to maintain the equipment intact, and an appeal to Moscow resulted in an order to leave the school undisturbed. In two important matters reforms were instituted by the communists; girls were admitted to the school, and summer classes for adults were instituted. These changes were of course in line with the declared policy of the government, and with a progressive attitude toward education. There are many women teachers in the school, and we were told that in the classes women, as with us, usually stood higher than the men. Considerable attention is given to music and drama; there is a "Little Theatre," and in one of the rooms we found the students' band learning to play the "International." All the windows have black blinds, so that the cinema can be used by day. The youngest pupils in the Commercial School are 14 years of age.

There is no doubt about the genuineness of the desire for education, and there is no domination by athletic interests such as we have in America. Our interpreter, Mr. A. I. Lavrushin, had been educated in the Commercial School, and I trust he will forgive me for referring to the scope of his knowledge as illustrating the thoroughness and breadth of the course. He had not only learned to speak English, but had acquired a remarkable familiarity with English literature. He knew the principles of physics, chemistry and biology, and could go out in the forest and call the trees by their scientific names. He had been on biological excursions, and in general had advanced to a degree which we should consider quite unusual in the product of a secondary school.

While referring to educational institutions, we should not omit the Y. M. C. A., conducted by an American, Mr. B. Lewis, assisted by Mr. Ivan M. Yaroslavtzeff, a Russian who graduated from the University of Chicago. Mr. Lewis told us that when the "Reds" were coming, the Y. M. C. A. had decided that it could do nothing but leave, but at the last moment it was thought best to remain and see what happened. The Communists appointed a committee of investigation, and after a considerable time reported favorably. They required, however, that the society should admit members regardless of religious affiliations, and the official name was changed to Society Mayak, the Lighthouse Society. In the large hall is a paint-

ing showing a lighthouse sending its rays into the darkness of the night, and a family group pointing to it as a haven of refuge. Actually, the operations of the society are exactly what they were before, and it is doing a great deal of work, of a kind much needed in Siberia. It seems to me that the time is ripe for the establishment of a Y. W. C. A., under whatever designation the government would permit.

When we reached Vladivostok, we found a very interesting exhibition of the products of the Marine Province, which was a little later transmitted to Moscow, to be included in the great exposition of the resources of all Russia. This exhibit had been prepared with the aid of a very substantial grant from the central government in Moscow, and was remarkably comprehensive in its scope. There were hundreds of bags of agricultural seeds from all over the province, and when I asked whether it would be possible to get samples of these for the U. S. Department of Agriculture, I was given a complete set, with no other charge than that for putting the seeds up in envelopes and labelling them. Our department has sent a collection of the seeds of cereals in return. I saw also a very fine collection of Lepidoptera, furnished by Dr. Arnold Moltrecht, of Vladivostok, one of the most learned and enthusiastic lepidopterists I have ever met. Dr. Moltrecht, when I was leaving, gave me a most valuable series of Siberian moths and butterflies for the U. S. National Museum, and I am indebted to him for the names of Lepidoptera which we collected, mentioned in this paper. At the cinema theatre we saw another part of the exhibit, moving pictures showing the activities of the province in great detail. It was not necessary, however, to go to the theatre to see "movies" The government had a "movie" show on the main street, the lantern being on one side of the street and the pictures projected on the other. Any evening one could see a crowd gathered, blocking the sidewalk. Once as we went by, we stopped to see what was offered, and it proved to be a reel of the wonders of California, the ostrich farms, artesian wells, and so forth. Later came some propaganda pictures, but then the crowd began to move away.

The first day in Vladivostok, I went out in search of insects, and got a number of things amongst the grass and weeds at the side of a road near to the hotel. The vicinity of the city is, however, very barren, and for profitable collecting it is necessary to go several miles. As I collected, both children and adults would occasionally stop and show a friendly interest, or even lend assistance; but in no case was I pestered for small coin, as I nearly always was in Madeira. Entomology was by no means an unknown pursuit, and during my stay in the country I came across several amateur collectors.

Our first excursion, under the direction of our guide and interpreter, Mr. Lavrushin, was to Okeanskaja, a sort of suburb about an hour's train journey distant, on the Gulf of Amur. It is not on the open ocean, as the name might suggest, but on a secluded and shallow bay, where the water is calm and warm, and the people come in great numbers during the summer to bathe. There is no town, properly speaking, but only a great number of small houses or cottages among the trees, often with very beautiful gardens. These summer cottages, known as datchas, are delightful places to spend the hot summer months, and the fare on the train, for those who have to work daily in the city, is very small. We were surprised, however, to hear a friend state that she and her little daughter wished to go to their datcha, but did not know whether they could, as it was necessary to get a medical certificate. I supposed of course that the certificate would show the absence of infectious diseases, but this was an entire misconception. The Communists had looked with displeasure on these evidences of bourgeois luxury, but concluded that it was quite legitimate for people to live at the seaside if they were out of health and needed recuperation. So far as we could judge, there was little difficulty in getting the required certificates, and the cure generally seemed to be extraordinarily rapid. But I am not the one to scoff, for it actually happened, later on, that a beatific day at Mme. Polevoi's was the turning point in a bad attack of bronchitis which I had developed in the hills.

Almost the first thing we noticed, on getting off the train at Okeanskaja, was an abundance of the familiar *Rosa rugosa* of our gardens. Here it is a wild plant, and it was very interesting to see that it was confined to the immediate coast, its thick leaves being an adaptation to maritime conditions, though retained when it is artificially grown inland. Maack, who explored the Ussuri country long ago, and collected the flora extensively, evidently did not visit the coast, for he did not get *Rosa rugosa* at all, but only species then referred to *R. cinnamomea* and *R. acicularis,* very similar to our wild roses of the Rocky Mountains. I looked for parasitic fungi on the *R. rugosa* at Okeanskaja, but found only a very sparing infestation, which Dr. Arthur tells me is *Phragmidium rosae-rugosae* Kasai, so far as it is possible to determine from the aecial stage alone. Another plant we soon saw, not previously familiar, was *Actinidia kolomikta* of Maximowicz, very remarkable for the variegation of the leaves, with large pallid, strongly pinkish areas, looking as if diseased, but perfectly natural. This would be an interesting plant for genetic studies similar to those recently carried on by Professor Bateson. The variegation, at least in the specimens I preserved, is confined to the upper side of the leaves.

The wild flowers at Okeanskaja are abundant and beautiful, and are not spoiled by the holiday-makers, although every Sunday the trains bring as many people as they can carry. This restraint is evidently not due to lack of appreciation of flowers for home decoration, as all summer long the flower-vendors abound in the streets of Vladivostok, and seem to have a flourishing trade. Going a little way into the woods, we presently found the fire-flower, *Lychnis fulgens,* the flowers large and of the most brilliant scarlet imaginable. The day was unfortunately wet, so we did not get a single bee. The wet weather was favorable for snails, and turning over some logs, I soon came across the fine species *Eulota maackii* and *E. middendorffii* of Gerstfeldt, originally described in Maack's great work on his travels in the Ussuri country. I noticed that these snails entirely lacked the dark dorsal band on the animal, which is so conspicuous in the common Japanese species assigned to *Eulota.* After getting home, I dissected both Siberian and Japanese species, and have no doubt that the Japanese ones should be placed in a distinct genus, for which Pilsbry's name *Euhadra* is available. While we were turning over logs, Lavrushin suddenly called ont that he had found an animal new to him. It was a salamander, *Salamandrella keyserlingii* of Dybowski; my determination was later confirmed by Dr. Stejneger. This little animal is confined to Eastern Siberia, but it goes north to southern Kamchatka, and inland to Lake Baikal.

The deposit of fossil insects was on the coast, about 400 miles northeast of Vladivostok, in N. Lat. 46°. There are no roads up the coast and the topography of the country makes them impossible without extensive engineering operations. The only way to make the journey is in one of the small steamers which go up as far as Sachalin Island or Nicolaievsk during the summer, stopping at all the coast villages on the way. We arranged to go on the "Aleut," but had to wait some time before she had all her cargo assembled and was ready to go. A special permit was necessary for this journey, and in filling out our papers we were asked for our "Russian" names. Fortunately, through the advice of a friend, we were prepared, and I wrote down Fedor Ivanovitch, while my wife signed Marta Josefovna. These familiar names, composed of one's given name and that of one's father, are used in ordinary intercourse, and a woman consequently keeps her original name, no matter whether she is married. We finally got away late on the evening of July 11, sitting up late to watch the receding lights of Vladivostok, as we steamed out of the bay. The next morning we arrived at Preobrageniya Bay, a small coast settlement. We had only a very

short time, but were able to note the coast flora,[2] *Lychnis fulgens, Rosa rugosa, Thermopsis fabacea, Bistorta,* a small blue *Iris,* apparently *I. sanguinea,* and especially the magnificent *Trollius ledebourii,* the orange flowers with long strap-shaped erect petals and large circular sepals. I pinned 21 insects from this locality, including *Argynnis aglaia* L., the Dark Green Fritillary of English collectors, a butterfly which extends from one end of the Palearctic Region to the other. A second stop on July 12 was at Valentine Bay, where I noted a luxuriance of flowers, *Geranium eriostemon* and what I supposed to be *G. sibiricum, Thermopsis, Corydalis,* with large yellow flowers, *Spiraea, Valeriana, Lamium* near *L. album,* but with delicately pink flowers, *Astragalus, Chelidonium, Polemonium, Viburnum, Philadelphus* and an orange *Hemerocallis.* There were also oaks, with galls upon them. The time allowed was so short that I pinned only seven insects. *Geranium eriostemon* is a very fine purple-flowered species.

Between Valentine Bay and the next stop (Low Lighthouse), Lavrushin found a handsome moth on the vessel; it was later determined by Dr. Moltrecht as *Odonestis pruni* L., which extends from Eastern Asia to Central Europe, but is absent from England.

On July 13 the "Aleut" put in at Low Lighthouse, where we observed an ornamental *Thalictrum,* with white flowers, *Mertensia maritima* and *Lathyrus maritimus* on the shore, the usual *Rosa rugosa,* etc. I obtained nine insects and a spider. The *Mertensia* and *Lathyrus* are also found on the North American coast.

Later in the same day we arrived at Olga Bay, a beautiful secluded harbor, where we had some hours, permitting an excursion into the woods. Here for the first time we saw peonies growing wild, the flowers white flushed with pink. We had earlier seen them offered for sale in the streets of Vladivostok. The species appeared to be *Paeonia albiflora* Pallas, judging by the general characters and number of petals. Later, when we got to Amagu, we saw Japanese sailors with large bunches of these peonies, carrying them to their ship.

At Olga, Lavrushin found a remarkable bright red polyporid fungus, quite new to me. Through Dr. Britton it was later de-

[2] Before going to Siberia, I copied out short descriptions of many of the recorded plants belonging to the more interesting genera, and these notes, in a small book which I kept in my pocket, enabled me to determine a good many species in the field. In Vladivostok I had the advice of Mme. Kryshtofovich, a very keen botanist, and she kindly supplied me with a long list of the typical plants of different stations in eastern Siberia. Finally, Mr. J. K. Shishkin placed in my hands a named collection of the plants of the Maritime Province; this is now in the New York Botanical Garden. I may also add that I made many notes from Regel's "Ussuri Flora" in Maack's volumes, in the library of the Vladivostok Museum.

termined as *Pycnoporus cinnabarinus,* originally described in 1776 from Carinthia. It is of circumpolar distribution; a second species of the genus occurs in all tropical regions. A satyrid butterfly taken at Olga proved to be *Parage achinoides* of Butler, a far eastern race or variety of the European *P. achine.* This is one of the numerous cases in which the Lepidoptera of this region are appreciably different from their European relatives, yet so close as to be considered races of them. Because the European types were first described, one gets the impression that the Siberian forms have varied from them, but it is of course possible in any case that the far eastern race is the stem or original form of the species, or that both are derived from an ancestor now extinct. We also took the little moth *Miltochrista miniata,* with a beautiful red margin to the wings; a species extending from Europe to Japan.

By the time we got to Tutihe, on July 14, there was a good deal of sea running, and I was in poor form. Mrs. Cockerell and Lavrushin went on shore, and brought back a few insects and a bunch of flowers, including *Petasites, Hieracium, Polemonium, Silene, Iris, Trollius, Geranium* and *Lychnis fulgens.* All these genera are common to North America, but the species are different. The sea got so bad after this that I was totally incapacitated, and felt very much discouraged when it was reported that the captain might pass Amagu Bay altogether, the landing facilities there being poor, and the shore exposed. However, when we finally arrived on July 16, they put us off in a lighter, and at last we stood on the shore which had seemed so distant and difficult of access. The greater part of the population of the small village was there, to see who had arrived and to hear the news. They have no other means of contact with the outside world; no telegraph or wireless. During the long winter months, when the coast is icebound, they are quite isolated. The people at Amagu belong to a sect called the "Old Believers," which separated from the orthodox Russian Church long ago, and went into the wilderness, like the Mormons, to seek security and peace. We were told that they had never had a school, though there had been a little private instruction. The government now expects to establish schools throughout the region, and even in this remote spot we saw the government propaganda in the form of small posters, one of which read: "Without cooperation, not even a plow; with cooperation, a *tractor.*" The district is a rich one agriculturally and quite capable of supporting its population. There was a Japanese vessel in the offing, as the Japanese have a "concession" at Amagu for the cutting of timber. This fact led to an incident which illustrates the almost instinctive nature of Japanese politeness. On our way to the village, we had to cross a small creek on a log. Mrs. Cockerell was half way across, when she seemed to

stumble. A well-dressed Japanese was just in front and before she could slip he was in the middle of the stream, holding out his hand. Would a member of any other nation have shown such prompt and self-sacrificing courtesy? Even Sir Walter Raleigh, in the famous story, undoubtedly saw Queen Elizabeth coming, and had time to consider what he would do with his coat. We spent the night at the house of Mr. Shareipoff, the head man of the village, a tall handsome man, with a large family The next day we set off on foot for the fossil beds, Shareipoff following with a wagon containing our belongings. Our way lay through cultivated fields at first, then into the forest country for about four miles. Beyond, in the distance, we saw the great Sichota Alin range, the peaks unexplored by the naturalist, but as inaccessible to us as the mountains on the moon To enter that country we should need a large party, to cut trails and give security from bandits, and the undertaking would require more time and money than we had to spare. Nothing could be more charming than the country we had reached, so far as the eye was concerned; but we soon realized its principal drawback in the shape of innumerable mosquitoes and horse-flies. Nowhere else had we seen them so abundant and so persistent. We had veils, and a large Japanese mosquito net to sleep under, but in spite of this we were badly bitten. At sea, Mrs. Cockerell is immune from seasickness, while I suffer miseries; but on land, I am not seriously affected by insect bites, while she is extremely susceptible, whether in Colorado or Siberia Thus our stay on the Kudia River was not without its disadvantages, in spite of the beautiful country and good collecting. We went first to look at the fossil bed, which occupies a very limited area on one side of a bend of the Kudia River, hardly a hundred yards of exposure. To make matters worse, since the time of Kuznetzoff's visit, the clay bank above had fallen down, so that the fossil-bearing rocks were covered by talus, which it was necessary to remove. The whole slope was at a maximum angle, and began to slide at the least disturbance, while fresh lumps of the clay rock frequently dropped from the cliff above. In spite of these difficulties, we at once began to find specimens of the commoner fossil plants of the locality, such as *Sequoia langsdorfii, Ginkgo adiantoides, Alnus corylina (A. corylifolia),* etc. A piece of fossil bark, with lenticels, was, I thought, from the *Alnus.* There were at least three species of *Pinus* (pine tree), with two, three and four needles to the bundle, respectively. The present flora of the region includes no 3-needle pines, nor any *Sequoia* (which is confined to the western coast region of America), nor *Ginkgo.* The maiden-hair tree, *Ginkgo biloba,* is common in cultivation in the United States, and is the sole survivor of a once abundant tribe. It is considered doubtfully indigenous in one locality in China, but

probably would be extinct, had it not been taken into cultivation long ago. During our stay on the Kudia River, we did our best to make a good collection of fossils, but the locality is not nearly so prolific as Florissant or the Roan Mountains in Colorado. Some of the best fossil insects were found by Lavrushin in the bed of the stream. On finally writing up the insects, I found I had 21 new species, including four new genera. The only Hymenopterous insect was a well-preserved wing of a leaf-cutting bee, *Megachile*, still showing the dark color with pale base, as in some living Indian forms. The Diptera consisted of six species of *Plecia*, a genus which was extremely prolific in Tertiary times, but is now represented by comparatively few forms. The Homopterous insects were fine and varied, one resembling a moth. There were also several beetles and caddis-flies, as well as their cases. The types of all these are now in the United States National Museum, and have been photographed by Dr. R. S. Bassler. The beds are of course of Tertiary age, and I think probably later than Eocene, but at present the exact age can not be determined. Unfortunately, no mammalian fossils have been found. The fossils indicate a climate which was not tropical and very likely not hotter in the summer than at present, but free from the cold winters of the modern Siberia

We pitched our tent close to the Kudia River, but owing to the dense forest and other conditions, it was not possible to establish ourselves very close to the fossil-bed. The river is swift, clear, cold and shallow, bordered by alders almost exactly like those found fossil and poplar trees with very sweet-scented foliage, *Populus suaveolens*. In it we observed trout, which seem to represent a race of *Salvelinus malma*, originally described from Kamchatka. It is a form of this fish which is known as the Dolly Varden trout in this country. We were reminded that we were in the Palearctic region by continually hearing the voice of the cuckoo, just as in England. Some mouse-traps were brought, and close to the tent we got numbers of a white-footed mouse resembling our American *Peromyscus*, but really belonging (as Dr. G. S. Miller tells me) to *Apodemus*. We also caught a red-backed vole and a shrew. One morning, just at dawn, we heard a number of rifle-shots not far away, and on going to the village next day learned that the hunters had shot a male moose, with the horns in velvet. The animal weighed 16 poods (Russian), and had very dark fur, almost black. We were told that the largest obtained in the vicinity weighed over 20 poods. The trees in the vicinity of our camp were noticeable for their beauty and variety. In open ground were larches (*Larix dahurica*). The lilacs (*Syringa amurensis*) grew tall, with very fragrant white flowers. The various species of maple, with elegantly cut leaves, seemed characteristically Asiatic. In the

meadows, perhaps the most characteristic flower was the orange *Trollius ledebourii,* occasionally presenting a variation with yellow flowers. The scarlet *Lychnis fulgens* occurred in patches. A columbine (*Aquilegia*) with dull purplish sepals grew by the river. The species of *Sedum* (stone crop) were very large and fine. A red currant was fruiting, and the small native strawberries were found to be delicious. The flora was enough to delight any botanist, but we could not give it much attention, being too fully occupied with living and fossil insects.

The collection of recent insects which we secured was large, being especially rich in butterflies, wood-boring beetles, Cetoniid beetles and sawflies. Bees proved to be local and not very numerous. Very few moths were caught at light, the commonest being a rather small form of the well-known currant moth, *Abraxas grossulariata,* which has been used so much for genetic studies in England. Minute beetles were collected in some numbers on the tent. Some of the larger Lepidoptera (determined by Dr. Moltrecht) may be cited as illustrating the character of the fauna:

(1) A beautiful yellow *Parnasius eversmanni* was caught by Mrs. Cockerell on a hill not far from our camp, July 25. The species was new to the U. S. National Museum; it occurs in the Altai mountains, Transbiakal and Amurland, but is represented even in Alaska by a race.

(2) *Colias* proved to be surprisingly rare; I took only *C. palaeno* race *europomene,* which occurs also in the European Alps.

(3) Of the whites, *Pieris melete* was common; it is a characteristic form from the Himalayas to Japan. In Amagu Village, near the sea, I took a perfectly ordinary cabbage butterfly, *Pieris rapae.* Has it been introduced?

(4) The only swallowtail was *Papilio machaon* race *ussuriensis,* a far eastern form of the common European species. Nothing was seen of the great *P. maacki,* which is so conspicuous in the southern part of the Maritime Province. On the way back, we first saw *P. maacki* at Valentine Bay, July 29.

(5) The silver-spots (*Argynnis*) were particularly numerous and varied. *A. daphne* extends to Europe. *A. anadyomene* is a species of China, Amurland, Japan, etc. *A. selenis* was originally described from the Ural Mountains. *A. neopaphia,* taken at flowers of *Sedum,* is a race of the common European *A. paphia.* The European *A. ino* was represented by a race *amurensis* and *A. adippe* by race *xanthodippe* and a form approaching *coredippe.* Thus six species in all.

(6) The European *Melitaea athalia* was represented by a race *amurensis.*

(7) The comma-butterflies were represented by *Grapta c-album,* which occurs even in England.

(8) The handsome black and white *Limenitis helmanni* was very common at our camp. It is a species of central Asia and China. A species still more suggestive of the country to the south was *Neptis thisbe,* which I took at the fossil-diggings.

(9) I was especially pleased to take *Pyrameis indica,* though smaller and not so well colored as it occurs at Okeanskaja. This insect reappears in local races at the other extreme end of the Palearctic region, being abundant in Madeira and the Canaries.

(10) The moths included the common European *Spilosoma lubricipeda*, and a local race (*askoldensis*) of the European *Cosmotriche potatoria*.

(11) We saw a sphingid, but could not catch it. A specimen of *Pergesa askoldensis*, native of Amurland and Japan, south to Askold Island, was taken on the "Aleut" between Olga and Amagu.

It will be seen from the above that the fauna is strictly Palearctic, and consists very largely of species which extend even to the Atlantic coast, though often subspecifically different at the ends of their long range. When we later collected in the southern part of the Maritime Province, we obtained many species not observed in the vicinity of Amagu and had the impression that the fauna was decidedly different and appreciably richer. There may, however, be some fallacy here, due to the fact that the Amagu collections were not only obtained a little earlier in the year, but the season so far north was necessarily much later than near Vladivostok. Thus, for purposes of more exact comparison, some one should visit Amagu toward the end of the summer, and make extensive collections. As an illustration of the difference in season, at Okeanskaja early in July the common touch-me-not (*Impatiens*) was in full flower. By the Kudia River we found the same plant, but the first flower was not noted until July 24. This would indicate at least three weeks' difference in the seasons. We found the days very warm all over the Maritime Province, at least when the weather was fine, but the nights on the Kudia River in July were uncomfortably cold.

The "Aleut" had gone on to Sachalin Island, and was expected to return in about twelve days. As other chances of getting back to Vladivostok were quite problematical, we decided to move down to the village and take the "Aleut." Owing to the absence of any means of communication, it is impossible to say exactly when a boat will arrive; and as the vessel only remains an hour or two in the gulf, it is necessary to be ready to go on board at any time of day or night. Furthermore, there are three different landing places, and it is hard to tell which will be used in any given case. Thus we spent a rather anxious night at Shareipoff's, and early in the morning some of the young men were on the roof of the shed, looking for signs of the vessel. Eventually she did arrive, and we hastened to the shore, only to find that the lighters were coming in half a mile or more away, and we had quite a scramble to get to the proper place in time. In the confusion, a wooden box containing our plant fossils and pickled mice was left behind, and we almost gave it up for lost. Through the kindness of Mr. Shareipoff it was put on the "Aleut" when next she called at Amagu, and reached Vladivostok only the day before our departure from Siberia. We repacked most of the fossil plants and sent them overland to Petrograd, where they will be studied by Dr. Kryshtofovich. A small series we placed in the Vladivostok Museum. In Japan, it

was only by a narrow margin that we escaped losing our collections at Yokohama; so it very nearly happened that the fossil plants, supposed to be lost, were the only things saved.

The return trip to Vladivostok was uncomfortable, owing to the stormy weather. On July 29, I went ashore at Valentine Bay, and the same day Mrs. Cockerell and Lavrushin had a short time at Preobrageniya Bay. Arriving at Vladivostok, the numerous passengers were delayed for examination by the authorities; but with our "mandate" we were able to leave at once, and proceed to the hotel.

During August we worked in two localities, Okeanskaja and Kongaus. On two occasions we were guests at the summer cottage of Mme. Polevoi, wife of a well-known local geologist. Through her kindly hospitality we not only had a very enjoyable time, but greatly added to our collections. I never saw so many butterflies in one locality as at Okeanskaja. The grandest of all, both here and at Kongaus, is the dark *Papilio maackii* of Menetries, originally collected by the explorer Maack on the Amur River. Other extremely fine species, taken near the railway station, are *Apatura schrencki,* known from Amurland to Corea, and *Limenitis populi* race *ussuriensis,* a far eastern race of a well-known European species. Another swallowtail, not seen at Amagu, was *Papilio xuthus.* I took a single *Colias* in fine condition, *C. poliographus,* usually considered a race of the European *C. hyale.* The Saturniid moth *Caligula japonica* abounds in these woods, as I was informed by Dr. Moltrecht, who stated that it was introduced from Japan some years ago. I found a cocoon, but was not there at the season for the moths. I also found the very curious bright green cocoon of *Rhodinia fugax* subsp. *diana* of Oberthuer, another Saturniid moth. The nomenclatural type of this species, *R. fugax* proper, inhabits Japan. The related *R. jankowski,* which Dr. Moltrecht took at Sedanka near Vladivostok, has a brown cocoon. Both species feed on *Phellodendron,* sometimes called Chinese cork-tree; a genus of plants which, like the moths, is represented by forms in the Siberian coast region and Japan. A specimen of a remarkable genus of sawflies, *Megalodontes,* was taken.

The amount of endemism exhibited by the east Siberian biota depends largely on two factors, one the species-forming tendency of the group concerned, and the other the habits, whether volatile or sedentary. Thus at Kongaus I was delighted to find the peacock butterfly, *Vanessa io,* which used to give me so much pleasure as a child in England. It extends from one end of the Eurasian continent to the other, practically unaltered. In Bartenef's account of the dragon-flies of the genus *Sympetrum,* it appears that species found near Vladivostok extend in several cases to Europe, in one to

Japan. But Kiritshenko, discussing the bugs of the genus *Aradus,* sedentary animals which live under bark, indicates quite a series of endemic forms in Eastern Siberia.

The train which takes one to Okeanskaja follows a winding track eastward among the hills to Kongaus, a village in the vicinity of the Soochan coal mines. From Kongaus a cable-railway runs over a steep hill, bringing the coal to be shipped to Vladivostok. We found at Kongaus a comfortable inn, with extremely moderate charges, conducted by Mr. and Mrs. Mortakoff. Our meals were served on the porch, shaded by grape-vines, while geese vociferated in the yard below The Russian word for goose, which we heard frequently, is practically the same as the English. In the garden were many flowers, and behind the house raspberries and vegetables. The potatoes were badly damaged by a coccinellid beetle of the genus *Epilachna,* closely allied to the bean-beetle of our country. We found both larvae and adults, and observed that the insect also fed on the wild *Solanum nigrum.* This beetle, if ever introduced into America, would be an extremely serious pest.

A great surprise at Kongaus was the discovery that the snail *Eulota maackii* was represented exclusively by a gigantic race (race *optima* Ckll.) the shells with a diameter of 32.5 to 36 5 mm. This was unexpected, because we had found the species uniform on the coast, from localities as distant as Okeanskaja and the Kudia River. The Kongaus race also seems to differ a little anatomically, but it is not certain that this is constant. Mr. Lavrushin found a beautiful yellowish-white mutation, without markings (form *albida*).

We were surprised at our failure to find several types of snails which are generally common in the Palearctic region. The circumpolar *Cochlicopa lubrica* turned up now and again, but not a single *Clausilia,* or Pupoid or Bulimoid form. Pilsbry has published a list of the snails of Corea, and although the northern boundary of that country is almost in sight of Okeanskaja, the molluscan fauna is extremely distinct. As there seems to be no physical barrier, it must be climatic. The complete list of genera of land molluscs we found in the Maritime Province is: *Eulota, Hygromia, Vallonia, Gonyodiscus, Polita, Euconulus, Cochlicopa, Succinea, Agriolimax.* All these except *Agriolimax* were found on the Kudia River; all except *Vallonia* and *Succinea* at Kongaus. All except the first two are genera found native in the United States. *Gonyodiscus ruderatus* (Studer) was very common. This species extends from Central Europe to the eastern coast of Asia, but in the British Islands is only found fossil. In spite of the damp climate and luxurious vegetation, it seemed for a time that there were no slugs whatever in the Maritime Province. But shortly before leaving Kongaus I

found, within the town limits, specimens which to all appearances (they have not yet been dissected) belong to the widespread *Agriolimax agrestis* and *A. laevis*. The former may have been introduced, but the latter surely is native. There is an old record of a *Philomycus* found up the coast north of Amagu, but this is an animal of warmer regions, and was doubtless introduced with Japanese or Chinese vegetables. Another apparently absent group was that of the Juliform millipedes, so common in Europe and America. We did find Polydesmids and centipedes, and also a Pseudoscorpion. Former glaciation may explain these apparent deficiencies in the fauna.

At the top of the hill beyond Kongaus there is an engine-house, for the purpose of operating the cables which haul the coal-trucks. This place is brilliantly lighted at night with electric lights, and attracts more moths than I have ever seen at light anywhere else. We also secured a number of moths at the lights of the guest-house at the bottom of the hill. Eventually the species thus obtained will be completely recorded, but it will suffice at present to mention *Notodonta torva,* which extends from Europe to Japan; *N. dembowskii,* confined to the Amur-Ussuri country and Japan; *Triphaenopsis pulcherrima,* which extends to India and China; *Plusia chryson,* found from Britain to Japan; *Lymantria aurora,* known from China, Corea, Amurland and Japan; *Cosmotriche potataria askoldensis,* a local representative of a common European species; *Paralebida femorata,* endemic in this region; *Dendrolimus pini,* found from Europe to Japan; a large goat-moth looking like the common European species, but probably referable to *Holcocerus vicarius; Spilosoma niveum,* a beautiful white moth with pink color on abdomen and legs, extending to China and Japan; and a form of the European tiger-moth, *Arctia caja.* At the flowers in the garden of the hotel we took the humming-bird moth of Europe, *Macroglossa stellatarum.*

Butterflies were also numerous at Kongaus, including a silver-spot we had not seen before, referred by Dr. Moltrecht to *Argynnis lysippe,* described from Japan. Lavrushin took a specimen of the mourning cloak (as called in America) or Camberwell beauty (as called in England), *Euvanessa antiopa.* He also collected a *Satyrus dryas,* a species extending from Spain to Japan.

A special feature of this country is its richness in the beautiful sphingid moths generally known as *Smerinthus,* but latterly classified by authors in several genera. Dr. Moltrecht collected no less than six species of these in and near Soochan. Three of them, *S. argus* (*planus*), *S. caecus* and *Amorpha amurensis,* feed in the larva state on poplars and willows; two, *Marumba jankowskii* and *M. maackii,* feed on lime (*Tilia*); the remaining one, *Callambulyx*

tatarinovi, feeds on elm. All these are exclusively far eastern, except the *Amorpha,* which goes as far west as Russia.

The small boys at Kongaus took a good deal of interest in our collecting and often assisted us. We were surprised to find that among these people the name "machaon" is used as a general designation for all species of *Papilio.* One day we were out in the forest not far from town, and Mrs. Cockerell and I wandered up a little trail, while Lavrushin went off to the left after a *Papilio* he had seen I was hunting for a satyrid butterfly, new to me, which I had just seen, when we suddenly looked up and saw a tall man standing in the way. At first we thought of Lavrushin, but a second glance showed a Chinese, with a long rifle and a deerskin on his back. Looking again, we saw the heads of many more appearing above the bushes. Seriously alarmed, we called out to Lavrushin, and walked toward him. He declared we must have met some Russian hunters, but would go and see. After a while he came back, and said they were indeed Chinese bandits. They shook hands with him, asked what we were doing and said we should not be alarmed. Lavrushin exhibited net and killing-bottle and said we came from Vladivostok and worked in the museum. He discreetly avoided reference to the fact that we were Americans. Lavrushin suggested that we must not appear frightened, so we strolled down the trail, and I caught the butterfly (*Lethe epimenides* of Menetries) which I had been looking for. Presently we came upon a young girl tending her cow, and in a little while we were in the village. Subsequently we were told that the bandits, some thirty of them, had come down to impose a levy of 600 roubles ($300) on the Chinese merchants of the town. The night after we saw them they all slept in a Chinese house only two doors from our inn. It seemed quite possible that they might decide to carry us off if they learned that we were Americans; and as the weather was by this time very wet and I had developed a severe case of bronchitis, we did not at all relish the prospect. A Japanese friend of ours, Mr. Noda, of Vladivostok, was thus captured not very long ago, and as it was in an out-of-the-way place it took about two months before he could get his ransom and his liberty. We were told that although these bandits had been known to kill a solitary hunter for the sake of his gun, they very rarely molested Russians. The Russian young men are good shots and used to the woods (as Kolchak found during the civil war), and their vengeance would be something to be afraid of. The trails are few, and if men leave them and go across country they can not travel fast. Also, as we ourselves found, it is usually easy to follow in the tracks of a traveller, owing to the large numbers of plants with the under sides of the leaves conspicuously

pale, these showing more or less after disturbance. Owing to the vast extent of unoccupied country, and the nearness of the Manchurian border, the bandit problem is not easily dealt with, but the government is doing what it can. We heard that some of those we saw were captured soon after we left Kongaus. These bandits do not pilfer, and it is almost true to say that they behave as decently as they can, consistently with their illegal and irregular mode of getting a living. Thus we were told of a case of a young Russian student who met a party of them when out in the woods. They demanded his pistol, but he said he was poor, and it had cost him a lot of money, and he could not afford to part with it. "Very well," said they, "we will pay you." They gave him some money on the spot and promised more when it could be procured. Presumably he never saw the balance, but robbers in other countries would not usually recognize any obligation to pay.

Returning to Vladivostok, we began making arrangements to leave. This proved to be no simple matter, and it may be worth while to recite the necessary operations for the instruction of future travelers. We were living in the building of the Geological Committee, and the first step was to get registered with the police as resident there. This having been done, we could apply for a permit to leave the place, and this we secured. The next step was to visit the office of the Political Government, where we showed our papers to a young woman who looked weary with all the routine. She at once put her finger on my passport and remarked that we had been in the country more than a month. Quite so, but what of it? Well, there had been passed, since we arrived, a law or regulation requiring all who remained more than a month to get a Russian passport. This was an appalling prospect, involving I know not what red tape and delay. So the young woman took us and the passport to the office of the head of the division, who proved to be a very young-looking man reading a newspaper. She thrust the passport before him, and he looked at it out of the corner of his eye, and went on reading. We wondered at his apparent rudeness, but later realized that he perceived the dilemma and, not wishing to hold us up, simply refused to pay any attention. So the distracted young woman went back to her office with us, and allowed us to proceed. We must, however, pay six roubles gold (three dollars) for a permit to leave, and this must be done at the treasury, about half a mile away. Arriving at the treasury, we presented our authorization to an official, who gave us a paper permitting us to pay the cashier. But the office hours are short, and there was a long line of people waiting to see the cashier, so we could do no more that day. Next morning Lavrushin was at the door when the

office opened and managed to get the six roubles paid. Then we had to wait more than an hour to get a paper from still another official, stating that payment had been made. With this, we returned to the office of the Political Government, and the third day thereafter received our official permit to go. But even this was not all, for we had to get our collections out. It was necessary to get a document from the Department of Education, and another from the Department of Commerce, declaring that these offices did not want our collections, which they had not seen. This accomplished, the customs official hardly looked at our things, and we finally boarded the "Hozan Maru" on August 22; glad to start homeward, but sorry to say good-bye to the many friends we had made in Siberia.

I wrote in a letter at the time: "As to the collections, it will of course be great good fortune if all comes through without breakage or mold—perhaps too much to expect, but we are certainly through the worst dangers, and there is a good prospect for success." Little did I realize what was in store for us at Yokohama, but nevertheless we did get through, practically without loss or damage Looking back at it all, it was rather a rash undertaking, especially for people beyond the plasticity of youth. We were often weary or uncomfortable, and on more than one occasion not far from disaster Yet we brought back precious memories as well as valuable collections, and eventually we hope it will appear that a distinct contribution has been made to Siberian natural history. It may be worth while to have demonstrated that something can be done with very moderate resources, in a limited time, without any backing from wealthy organizations. It certainly was worth while to come to know and respect the Russian people, and share their hope that after years of confusion and misunderstanding there will eventually arise a renovated nation which may teach the rest of the world some things it needs to know.

THE BORING HABITS OF THE SHIPWORM

By Dr. ROBERT CUNNINGHAM MILLER

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The method by which the smooth-walled, perfectly rounded burrows of the shipworm are excavated in wood has excited the curiosity of man since an early time In the first century A. D. the Roman naturalist Pliny the Elder remarked upon it. "What teeth (Nature) has given the teredo," he exclaimed, "even for perforating oak! . . . And also she has made from wood its principal nourishment."[1]

This conjecture as to the purpose of the denticles on the shell appears to have gone unchallenged until 1733, when the Dutch investigator Sellius[2] objected that the shell of *Teredo* does not appear adequate to the task of boring, especially in the harder woods. He believed the boring to be accomplished by a kind of suction with the foot, aided by the action of the water which is being continually taken into and forced out of the burrow.

The opinion of Sellius precipitated a discussion which has been carried on intermittently for nearly two hundred years. Certain experimental difficulties having interfered with direct observations of the shipworm in action, the debate has been more or less academic, the nature of the premises and the vigor of the discussion suggesting analogies with a well-known medieval controversy regarding the number of teeth of the horse.

While a majority of writers have favored the view that boring is carried on by movements of the shell, not a few have insisted that the burrows are excavated by a slow but continuous wearing away of the wood by friction and suction with the foot. Still a third group has maintained that a chemical action of some sort is involved in the boring process.

The theory of boring by means of the shell rests largely on morphological grounds. The shell of *Teredo* has been reduced, relative to the size of the animal, until it covers only a small portion of the anterior part of the body. It is a subglobular structure, gaping in front for the protrusion of the foot, and behind for the protrusion of the long, slender body. It consists of two valves, which are capable of rocking back and forth on specialized dorsal and ventral knobs, so that the anterior and posterior adductor muscles oppose

[1] Caii Plinii Secundi Historia Naturalis, Book XI, Chap. 1.

[2] Godofredi Sellii Historia Naturalis Teredinis seu Xylophagi Marini, pp. 78 ff. Trajecti ad Rhenum, 1733.

each other in action. The anterior portions of the valves are equipped with sharply denticulated ridges, the projections of which are directed outward and backward. The structure of the shell, coupled with the fact that the posterior adductor muscle is somewhat more than thirty times as large by volume as the anterior adductor, strongly suggests that boring is accomplished by movements of the valves, repeated contractions of the large posterior muscle causing their forward edges to spread apart and rasp the wood.

To this it has been objected by advocates of the theory of boring by means of the foot that the shell is inadequate to the task of boring, that it does not show signs of wear as would be expected if its function were that of rasping wood, and that the walls of the burrow of *Teredo* are too smoothly polished to have been rasped mechanically. It has been further pointed out that certain forms, such as *Patella,* are able to make depressions in rocks by means of the foot.

Proponents of the theory of boring by chemical means have little to offer in support of their views except a presumed inadequacy of both shell and foot to accomplish the observed result. Nevertheless, this theory had the backing of such authorities as Gray, Deshayes and De Quatrefages, all of whom during the nineteenth century made noteworthy contributions to the knowledge of marine borers.[3]

In order to determine if possible by direct observation which of the foregoing suppositions is correct, the writer recently tried the experiment of carefully opening the burrow of a teredo near the anterior end and sealing over the opening with a glass cover-slip, thus making a small window in the burrow, through which the movements of the occupant could be observed with the aid of a binocular microscope and a narrow shaft of light. Most of the animals disturbed in this fashion would retract about a third of the length of the burrow, so that they were entirely out of sight from the window, and after a few days' quiescence they would bore off in another direction. But after a number of repetitions the experiment finally proved successful. One specimen was found which carried on boring operations directly in view of the small glass window, and the process was observed in considerable detail.

The boring is accomplished by rasping with the valves, which are held in position by the combined action of the foot, attached to one wall of the burrow, and the dorsal fold of the mantle, distended by turgor, pushing against the opposite wall. The typical boring position is seen in Fig. 1a.

[3] Readers who desire a fuller account of the various theories of boring are referred to Miller: "The boring mechanism of *Teredo*," Univ. Calif. Publ. Zool., vol. 26, pp. 41–80. 1924.

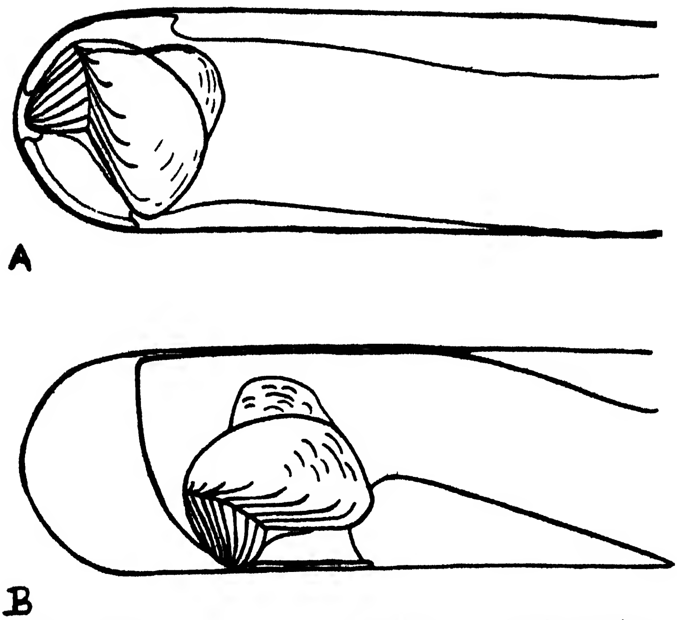


FIG. 1. *Teredo*. a. Typical boring position. b. Boring position when beginning a side passage at a right angle to the former course of the burrow.

The effective stroke of the valves is the outward and backward one, as had already been assumed from the direction of the points of the denticles on the shell, and from the extraordinary development of the posterior adductor muscle. At each stroke of the valves the foot takes a new hold. As the backward stroke of the valves is completed, the foot is relaxed and its margins spread out so far that they overlap the edges of the shell. Then, by a sudden contraction, the margins of this structure are drawn in and the valves brought forward into position for a new stroke. Then follows the slow, labored contraction of the large posterior adductor, causing the forward edges of the valves to spread apart and rasp the wood on their outward thrust. That the valves do actively scrape the wood on this stroke is indicated by the fact they were observed frequently to slip, the backward margins being drawn together with a jerk instead of the usual slow, steady pull. The boring movements occurred rhythmically, from 8 to 12 times a minute.

The anterior tip of the burrow is mined out by the anterior lobe of the shell; the movement of the shell is necessarily in a direction longitudinal to the ridges of this area, so that their serrate edges act upon the wood as so many small saws. The serrations on the ridges of the anterior area are extremely fine, as compared with the

FIG. 2. Shell of *Teredo navalis* mounted in position at end of burrow, x 10. a. Dorsal view, b. Lateral view.

denticulations of the anterior portion of the median lobe of the shell, and hence better fitted to act as the advance boring edges. Also the shape and position of the anterior lobe especially adapt it to working in the extreme tip of the burrow (see Fig. 2). The marks of the work of the anterior lobe of the shell are often plainly evident on the wood (Fig. 3).

While the ridges of the anterior lobe are working saw-fashion in the tip of the burrow, the coarser, wedge-shaped teeth of the anterior portion of the median lobe of the shell are at the same time working rasp-like, enlarging the diameter of the burrow and advancing the peripheral portion of its cupped extremity. Thus, while the tools might be compared to saw and rasp, their work is in effect that of drill and reamer.

The disposal of the rasped-off particles of wood it was not possible to observe, because of their minute size. There is, however, every reason to believe that they are swept by the cilia of the periphery of the foot into the range of the cilia of the esophagus. Apparently all the rasped-off wood passes through the digestive tract, where a considerable portion of it is utilized as food by the animal,[4] as Pliny had further surmised.

The position assumed by *Teredo* in boring off at a right angle to its former direction of progress is seen in Fig. 1b. One would hardly have supposed that such an awkward position is assumed by the animal in changing the course of its burrow, were this not

[4] *Cf.* Dore and Miller: "The digestion of wood by *Teredo navalis*," Univ. Calif. Publ. Zool., vol. 22, pp. 383–400, 1923.

FIG. 3. Cupped extremity of a burrow showing marks of the work of the shell, x 10 a *Teredo navalis*. b. *Teredo diegensis*.

actually a matter of observation. Apparently the valves function without difficulty under such circumstances. This explains how *Teredo* is able to make the abrupt changes in the course of its burrow which are so often found, especially in heavily riddled piling, where such changes of direction are necessary in order to avoid breaking through into neighboring burrows.

The commonly made statement that one *Teredo* will never bore into or cross the burrow of another is not, strictly speaking, true. Occasional instances have been found in which one burrow passed directly through another. Such cases are rare, however, and it is probable that the first animal was dead before the second entered its burrow, as otherwise it would doubtless have been able to protect itself by a thickened wall of nacre. In heavily riddled timbers the teredos will sometimes adopt unusual expedients, such as to cross a crack of considerable magnitude in order to find new wood to attack. One instance was observed in an aquarium where a teredo had bored completely through a piece of wood, so that its shell and the anterior part of the body protruded into the water. This animal was doubtless abnormal.

The foot appeared, from observation, to be an organ of sense and a means of limited locomotion about the narrow confines of the burrow. The animal under observation through the window made in the burrow was seen to turn from left to right and back again a number of times, as though exploring the wall of the burrow with

the foot, before it made any boring movements. Probably thus in some way *Teredo* becomes aware of neighboring burrows, so as to turn aside and avoid them. In executing these turning movements, the foot several times passed directly across the glass, so that the manner in which it functioned could be well studied. The organ was first flattened against the surface of the glass, and its margins spread out so that they extended beyond the edges of the shell. Then, apparently by contraction of the retractor muscles of the foot, the margins were rather suddenly drawn in and the central disc of the foot slightly cupped, obviously constituting a sucker. After each contraction the foot sought a new attachment, moving laterally about 0.5 mm and hitching the shell along to a new position.

During the course of this exploration of the walls of the burrow, the animal was observed to turn about its long axis 260 degrees in one direction and 220 degrees in the other, or a total of 480 degrees The body was obviously twisted, owing to the animal's being attached to the burrow at the posterior end, but this twisting appeared to occasion it no inconvenience. Thus is solved the problem of how the shell can be brought into the various positions necessary for excavating the regularly cupped, perfectly rounded burrow. It was obvious from the markings shown in Fig. 3 that the shell must have been rotated by slow stages through at least 180 degrees in each direction in order to produce the striations radiating in all directions.

The further possibility that *Teredo* might facilitate its boring by the use of some secretion which has a solvent action on certain constituents of the wood was also investigated. It would seem that the action of such a substance, if it occurs, should spread at least for a limited distance through the cells of the wood at the extremity of the burrow. The tracheids of Douglas fir are from 1 to 3 mm in length, and it is hardly conceivable that a secretion applied to one end of a tracheid should not spread through its entire length Probing in the extremity of the burrow with a needle, however, did not reveal any area of softened wood, as would be expected on this hypothesis. Micro-staining with hematoxylin, which is a selective stain for cellulose, did not reveal any diminution in the cellulose content of the wood at the end of the burrow. It was further attempted to compare quantitatively the composition of shavings of wood immediately adjacent to the burrows of *Teredo* with that of shavings from sound portions of the same timber. An analysis of these samples did not indicate that any substances had been removed by the enzymes of the borer from the wood forming the wall of the burrow.

While the writer does not consider that the possibility of the use of a glandular secretion to facilitate boring is definitely disproved by these experiments, the evidence strongly indicates that boring is performed entirely by mechanical rasping of the valves on wood that has been to some extent softened and macerated by the presence of water in the burrow.

The experiment was tried of rasping the surface of a piece of Douglas fir wood under water with a medium-sized teredo shell held between the thumb and forefinger By this method a depression 6 mm in diameter and 1.2 mm deep was made in 30 minutes, at the end of which time the denticles of the shell, examined under the microscope, showed not the least trace of wear. A similar attempt to rasp dry wood, however, resulted in the speedy destruction of the shell. Thus it appears that the action of water alone is sufficient to greatly soften the wood and accordingly facilitate boring. The assumption of a chemical action on the wood by some unknown secretion produced by the borers is quite unnecessary.

It is not the intention of the writer to defend the somewhat moth-eaten scientific reputation of the blandly uncritical Pliny, but in this instance at least he appears to have hit upon the right conjecture, both as regards the mechanism of boring and the utilization of the wood as food. It was perhaps the very simplicity of the actual method of boring of the shipworm which led so many later investigators to overlook it in a search for some more obscure explanation.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

GASES HEAVIER THAN LEAD

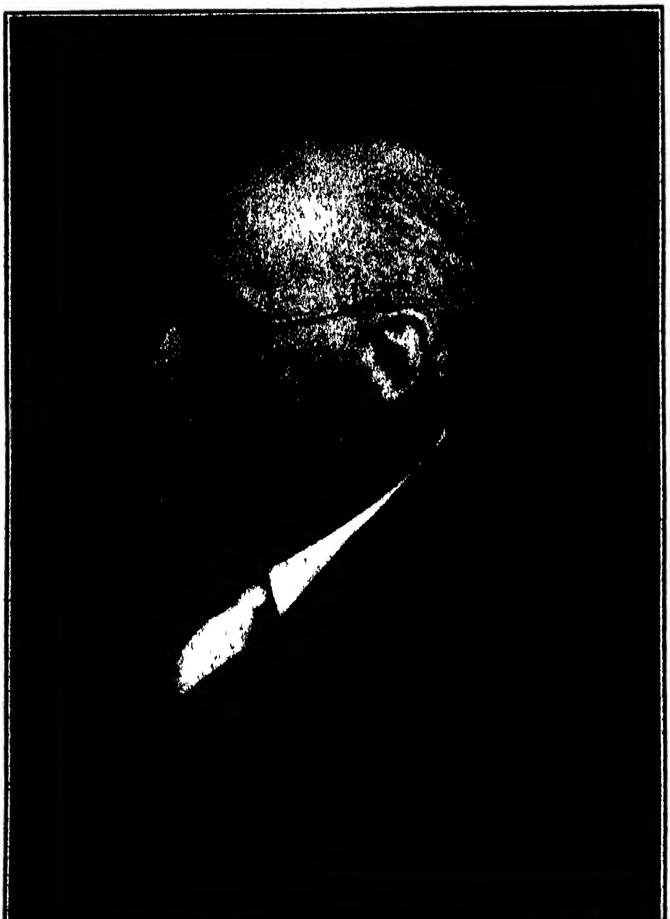
PROFESSOR A. S. EDDINGTON, of Cambridge, can spring more sensations in a half-hour talk than any other sober-minded scientist I ever heard. He broke the record at the Toronto meeting of the British Association for the Advancement of Science when he expounded his new theory of the constitution and evolution of the stars An old-fashioned physicist, if any such were in the lecture room, must have been shocked to hear him talk so calmly of gases more than fifty times heavier than platinum, of temperatures over twenty million degrees centigrade, of light waves that are lengthened by gravitation, of chemical elements losing their identity, of stars puffed out by the internal pressure of X-rays, of dwarf stars that are giants at heart, of gases made up of mere electrons and nuclei, of matter converted into energy and of stars that are dissolving into light.

If these were mere speculations, such as some astronomers indulge in, Camille Flammarion for instance, nobody need mind, but Professor Eddington insists and persists in proving his points. He began by working out the mathematical theory of star formation on the assumption that its substance behaves like a perfect gas. Then on plotting the observational data of stars of all sorts these were found to fit closely to his theoretical curve, even our own sun which has a density one and a third times greater than water. From this he concludes that stars in general obey the laws of perfect gases, regardless of their density, and that their luminosity depends mainly upon their mass, the density making comparatively little difference.

Some stars seem to have a density heavier than platinum. For instance, the faint companion of Sirius has a mass eight tenths as much as the sun, yet its size, as judged by its light, must be so small that its density should be fifty thousand times that of water. Whether its mass is really so great may be determined by observing the Einstein shift in its spectrum and this is now being tested at the Mt. Wilson Observatory.

The new theory conflicts with the theory advanced by Professor H N. Russell, of Princeton, and now commonly held, that stars start out in life as red giants of extreme tenuity, that heat develops as they contract, and that they get hotter as they lose heat, until they become white hot and then gradually cool down to red heat again. Professor Russell, in spite of the fact that a hard blow had been dealt at the theory which had given him an international reputation, was the first to congratulate Professor Eddington on his achievement. "I take off my hat to him," he said, "for this is the second time he has deduced from mathematical principles what ought to have been obvious, but was not perceived before."

A possible agreement between the rival theories may be brought about by invoking Einstein's idea that matter may be converted into energy and radiated off into space. Professor Eddington says: "It is possible that a star may gradually diminish in mass during its evolution. This would



SIR WILLIAM BAYLISS

The distinguished British physiologist, professor of physiology at University College, London, noted for his work on the circulation and a number of physicochemical problems in physiology, who died on August 27.

happen if it obtains its energy of radiation by annihilating electrons and protons, thus burning itself away."

According to Professor Eddington's theory, stars continue to get hotter as they shrink until the central temperature is over ten million degrees Centigrade. At this heat the atom of the heavier elements would be stripped of its outer electrons and the atom of the lighter elements, like carbon and oxygen, would be reduced to the bare nucleus. The atoms in the stars would then have only about one hundred thousandth of the bulk of ordinary atoms, and such a gas could be compressed a hundred thousand times further than the gases we deal with on earth before the atoms begin to get crowded. In such a state all the stellar gases must have about the same molecular weight, 2 1, whatever may be the elements that compose them.

When I was young, astronomers used to try to scare us by telling us that the sun and stars were slowly cooling down and at length the universe would be left all dark and cold. That did not worry us enough, so now they have changed their tactics and prophesy a time when the elements shall melt with a fervent heat and the sun shall be no more. This sounds more alarming, for it would be worse for the human race to be roasted alive than frozen to death, and the idea that the solid ground may ultimately be dissipated into radiant energy and go rambling around a four-dimensional continuum forever gives one a new kind of shiver.

A GREEN-HEADED IDEA

As I was passing a florist's shop-window not long ago I saw a little image of a man's head in porous brown pottery, and on the top of it instead of hair there was a fine growth of grass, rising straight and thick from the forehead like Senator La Follette's hair. It occurred to me at once that this was a bright idea. For what good is hair anyhow? You can't pasture sheep on it, and you have to pay a barber to run a lawn mower over it and then he does not allow you anything for the crop. Now if we could grow grass instead it would cover the head quite as completely, and look as well—after we got used to the color—and, what further appealed to me, when the sod got thin the surface could be reseeded.

As I walked on the idea sank deeper into my brain. Would it not be possible that the grass growing on one's head might send down through its roots a constant supply of proteins, fats, carbohydrates and vitamins in the proper assortment so as to do away with the necessity of food? For it has always seemed to me a humiliating necessity, unworthy the dignity of man, that he should have to be dependent upon the plants for the fixation of solar energy that supplied his motive power. Just for lack of a little chlorophyl must man remain forever a parasite on plants? If man only had a head as good as a cabbage, he could accomplish the process of photosynthesis for himself.

Or, if man could not acquire the necessary chlorophyl, could he not form a close combination with some sort of plant life that possessed this power, as by farming out on shares any waste land he might have on his head? On looking up the matter I found, as I often do, that my idea was not so original as I supposed. I had, in fact, been anticipated by a million years or so, for certain sea creatures and land fungi, which, like man, were devoid of chlorophyl, had incorporated green vegetation which fed them the solar energy that they could not secure for themselves. The

DONALD B. McMILLAN

Who is now returning on the schooner *Bowdoin* from his expedition in the Arctic regions.

lichens have carried on such a partnership between plant and fungi for untold ages. The botanists call it "symbiosis," probably to avoid the commercial taint of the word "partnership."

But even though I had been beaten to it by the lichen, it did not appear that anybody had got a patent on symbiosis as applied to man. So I set about figuring out the acreage necessary for a home-grown dietary. I drew the outline of my hat band on a sheet of paper and laid it off in centimeter squares with a ruler. The area added up to 260 square centimeters. I sent this figure to a friend of mine who knows more about the value of solar radiation than anybody else, and asked him how many hours I would have to sit out in the sun to receive enough energy to equal what I now take in as food. My dietary I figured as roughly 3,000 calories a day on the average, including a rather hearty Sunday dinner.

He wrote back that I should have to have more of a swelled head than I had already to carry out the scheme. I did not understand what he meant at first, but on going over his figures I saw the difficulty. One square centimeter of the earth's surface at the equator receives from the sun, or would receive if there were no clouds or atmosphere, .00194 calories a minute. At the latitude of Washington and sea level, a square centimeter receives in the course of a year only about 152 calories. Accordingly the solar expert to whom I referred the question concludes: "For your requirements of approximately a million calories a year, the diameter of your head would have to be increased between five and six fold, in order to receive enough energy from the sun to sustain your mental and physical operations, and you would have to sit out in the sun all day long, every day in the year. These figures take account of the losses in the atmosphere and the obliquity of the rays, so you could hold your head up straight and not have to turn it around like a sunflower, as you suggest."

I do not easily give up an idea, so I measured my back and calculated its area, only to find that this, however well sodded, would not be a third large enough. Worse still I found that the green leaves are shockingly inefficient transformers of energy. They store up in the form of combustible or edible products only about one per cent. of the radiant energy they get from the sunshine. It would then take some three hundred mossbacks, working full time, to provide my necessary nutriment.

So I have been forced to admit that my scheme is impracticable, at least in its original form, but my figuring has the stronger confirmed my belief that some way might be found to make use of solar radiation for human purposes, without wasting more than ninety-nine per cent. of it, as is done by employing plants as intermediaries. An area of twenty square feet in latitude 38 degrees and at sea level, receives energy enough through the year, counting all the days as sunny, to give one horsepower continuously. If the weather is half cloudy forty square feet would amount to one horse power. This means that taking the country through each acre of land is getting more than a thousand horse power, and each square mile more than a half a million horse power of free energy from the sun, and yet we make no use of it except such infinitesimal fraction as may be converted into food or fuel by vegetation, or may raise water to the clouds to come down as rain and perchance to be caught by a water-mill, or may stir up the atmosphere to be used in running a few scattered windmills. It does seem to me that we might use a little more of this wasted wealth than we do. But the problem is too big for my head to solve.

FOREIGN COOPERATORS ON INTERNATIONAL CRITICAL TABLES

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A TABLE TRICK AND WHAT IT TEACHES

WHEN that stage in the dinner comes when everything has been cleared from the cloth except coffee cups and ash trays, and when those who do not smoke are toying with the extra lumps of sugar instead, then some one may remark: "It's funny that you can't set suger on fire with a match, isn't it?"

Everybody agrees that it is funny, so funny that they do not believe it. Sugar is food, all foods are combustible if they are not too wet. Those who know more about it are more positive; sugar is a carbohydrate and thus belongs to the same family as paper and wood. Why shouldn't it burn?

So they try it, setting up the domino on the saucer and holding a match to the edge or corner of it. But all they can get is a dull smoulder and a bad smell. The sugar softens, blackens but refuses to inflame.

They turn to the man who propounded the paradox and ask· "How do you explain it? Why can't you set sugar on fire?"

He takes his cigar from his mouth and remarks with a quizzical smile, "I can. What I said was that it is funny that you can't."

This starts a chorus of incredulity. "Let's see you," demand the skeptical. "Bet you can't," assert the mercenary-minded, who never take an interest in a conflict of opinion unless they have money at stake.

He accepts the challenge and perhaps the wagers. He sets up his lump of sugar, touches it with a match and it flames up promptly and goes on burning with a sooty flame.

Only the most observant of the tableful have noticed that he had first clumsily dropped the lump of sugar in the ash tray or with apparent inadvertence had touched it with the tip of his cigar. This is the secret of it, that a slight smear of ash from cigar or cigaret will so lower the ignition point of sugar that the heat of a match is sufficient to set it afire. Yet the ash does not act as kindling. It is not combustible. It has already been burned. And sugar alone will not inflame in the heat of an alcohol lamp, a gas jet or even the powerful Bunsen burner. It merely melts and chars. It may be consumed but does not burn freely.

This curious reaction has been thoroughly studied by Hedvall who had tried all sorts of chemicals on sugar in a Bunsen flame to find out what it is that causes the effect. The carbonates of sodium and potassium, such as exist in cigar ash, were among the most effective in lowering the temperature of combustion of sugar. Various other oxides of alkalies or alkaline earths, such as lime, will work the same. Zinc oxide is the best of all. The sugar touched by this will flame and crackle and burn completely.

Common salt and the sulfates of iron and copper will cause the sugar to burn, but only in part, leaving a black porous residue. Silica and the oxides of the heavy metals have no effect.

This simple experiment is a good example of what the chemist calls "catalysis." He does not know what it is but he has learned how to use it It has been found in many cases that the presence of a minute amount of an inert substance, like the ash here, will greatly accelerate a reaction and yet is not used up in the process. A finely divided metal often acts as a catalyst. Platinum is the best, but being so expensive some cheaper metal, such as nickel or iron, is more commonly employed. It is by means of such a catalyst that sulfuric acid is now made; that the nitrogen of the air is fixed for use as fertilizer in the form of ammonia or nitrates; that cottonseed oil is combined with hydrogen to form a solid fat. The use of catalysts is adding millions annually to the wealth of the world, yet in most cases the manner of their action is not understood.

THE INTERNATIONAL CRITICAL TABLES

International Critical Tables, organized under the auspices of the International Research Council, is a portion of an international scientific program, the responsibility for which has been assigned to the United States. The work is in charge of a Board of Trustees and a Board of Editors, appointed through joint action of the National Research Council, the American Chemical Society, and the American Physical Society, with headquarters at the National Research Council, Washington, D. C.

The work of preparing the data for the International Critical Tables is now actively under way. The material is being collected and critically evaluated by approximately 300 competent experts distributed among the following countries: United States, Canada, Great Britain, Belgium, France, Italy, Austria, Germany, Denmark, Switzerland, Holland, Australia and Japan.

The program covers all available information of value concerning all the properties and numerical characteristics of (a) pure substances, (b) physico-chemical systems of definite composition, (c) many industrial materials, (d) many natural materials, and (e) selected data for selected natural bodies or systems, such as the earth and its main physical subdivisions, the solar and stellar systems, and certain biological organisms, including man. Publications of the world in all languages will be combed for data and much unpublished information is also being collected. In addition to the stupendous scope of the tables, hitherto unapproached by any similar publication, the volumes will contain many novel features of arrangement. Thus, for example, not only will it be possible to find readily all the properties of a given substance or material but it will also be possible in many cases to ascertain readily what substance or material of a given kind has a maximum, a minimum, or a given value for any given property. This feature will be of great assistance in identifying a substance by means of its properties or in selecting a substance or material on the basis of a given property or combination of properties. The main descriptive material and the very complex index to the tables will be in four languages, English, French, German and Italian.

In order to assist the board of editors in connection with the work of the cooperating experts in foreign countries and in the collecting of information from these countries, ten corresponding editors have been appointed. These editors have greatly assisted the board in connection with the selection of competent cooperating experts. They have general charge of relations with the experts in their respective countries and also assist the board in securing data from their own and neighboring countries.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1924

THE MYRIAD-MINDED LEONARDO DA VINCI, FORERUNNER OF MODERN SCIENCE

By DON GELASIO CAETANI

ITALIAN AMBASSADOR TO THE UNITED STATES

It is generally believed that the Italians are eminently artistic, which is quite true; it is even believed that they are principally and solely artistic, which is perfectly wrong.

The fundamental and characteristic trait of the Italian race is its aptitude towards scientific speculation and towards technical achievement; and the marvelous artistic production for which my country is best known to the peoples of the world is essentially the fruit of a technical tendency to which the beauty-seeking temperament of the Italian people has given a superior artistic expression.

Dante was principally a philosopher and theologist, his purpose in writing the Divine Comedy was to expose his political and theological conception and, at a time when only Latin was used for literary purposes, he availed himself of a so far unused though marvelous vehicle of expression, which was the Italian language; in doing so, his we can well say superhuman artistic temperament gave to his thoughts an expression that has classed him as the greatest poet of the world.

Michelangelo, known principally as a painter and sculptor, was essentially an engineer and architect who ornamented the buildings and monuments that he was requested to construct. So were Bramante, Leonardo da Vinci, Benvenuto Cellini, Luca della Robbia and many and many others.

What is essentially characteristic of the Italian Renaissance, and even somewhat of the following periods, is not the large number of first-class artists who have revealed themselves, but the remarkably exquisite artistic form that was given to every object that came out of the hands of all Italian craftsmen. No carpenter seems to have been able to cut wood with his chisel, no blacksmith to forge iron with his hammer, no mason to lay stone on stone with-

LEONARDO DA VINCI'S PORTRAIT OF HIMSELF

out producing an object of art. The most marvelous manifestation of the Renaissance is not so much the production of its leading artists as that of its unknown artisans.

In the midst of this multitude of known and unknown men of genius one figure towers above all "from the belt upward," as Dante says of Farinata, and that is Leonardo da Vinci He is characteristically the engineer-artist of the Italian people and doubtless the most universal genius the human race has produced.

Certainly a majority of the people of the United States have heard or read of Leonardo da Vinci; probably nine out of ten know him as a great painter, but only one of these ten knows that his achievements as a technical genius are far greater than those as a painter.

Leonardo was born in 1452, in a village called Vinci, from which he took his name. He was the illegitimate child of an obscure public notary and of a woman of the peasant class

Brought up in poverty, Leonardo taught himself by watching others and by taking nature as his teacher. In talking about himself this forerunner of modern scientists and technical men says.

> I am fully aware that the fact of my not being a man of letters may cause certain arrogant persons to think that they may with reason censor me, alleging that I am a man ignorant of book learning Foolish talk! . . . They will say that because of my lack of book learning I can not properly express what I desire to treat of. Do they not know that my subjects require for their exposition experience rather than the words of others? And since experience has been the mistress of whoever has written well, I take her as my mistress, and to her in all points make my appeal.

A few years before America was discovered his personality had brought him into prominence at the ducal court of Ludovico il Moro in Milan.

I have not the space to give an account of his life and his achievements; therefore, I will limit myself solely to the enumeration of some of the astounding observations and discoveries that Leonardo da Vinci made.

These he formulated in laconic sentences scribbled with the left hand in the 5,300 sheets of his note-books that have luckily survived. He was left-handed and it came natural to him to write backwards, from right to left, in what is called "mirror writing" because it can be more easily read by using a mirror. He wrote carelessly for himself, making use of any space left around his sketches and drawings; philosophic consideration and scientific observations are strangely mixed up with unimportant memorandums and laundry bills. He was writing for himself, not for the public.

We now scrutinize with a lens his notes and sketches, gleaning in them with unceasing wonder the fundamental principles on which modern science and industry are based. It looks almost as if nothing had escaped his eagle eye. He understood the fundamental principles of astronomy, of paleontology and geology; he gave a description of human anatomy that can hardly be surpassed to-day; he invented the machine gun, the shrapnel, the Broadway elevated, the submarine; designed and tried a flying machine; made plans for a spring-driven automobile . . . and what not![1]

Maybe you remain incredulous: let me tell you. I am not going to attempt a coordinated and progressive exposition of his achievements, but will give a series of statements that convey more abruptly and more impressively the greatness of his genius. Whenever possible, I will use his words

In 1480, Leonardo wrote to Ludovico il Moro, Duke of Milan, offering his services and stating without much modesty all the things he could do as a military engineer and as an artist; it is a series of blunt statements made by a man who knew he could do what he said he would do.

The duke listened to his words. For fifteen years Leonardo served faithfully his lord, making good use of the opportunities that were offered him, or, as he expressed it himself in his notes:

> When fortune comes seize her with a firm hand and in front, I counsel you, for behind she is bald.

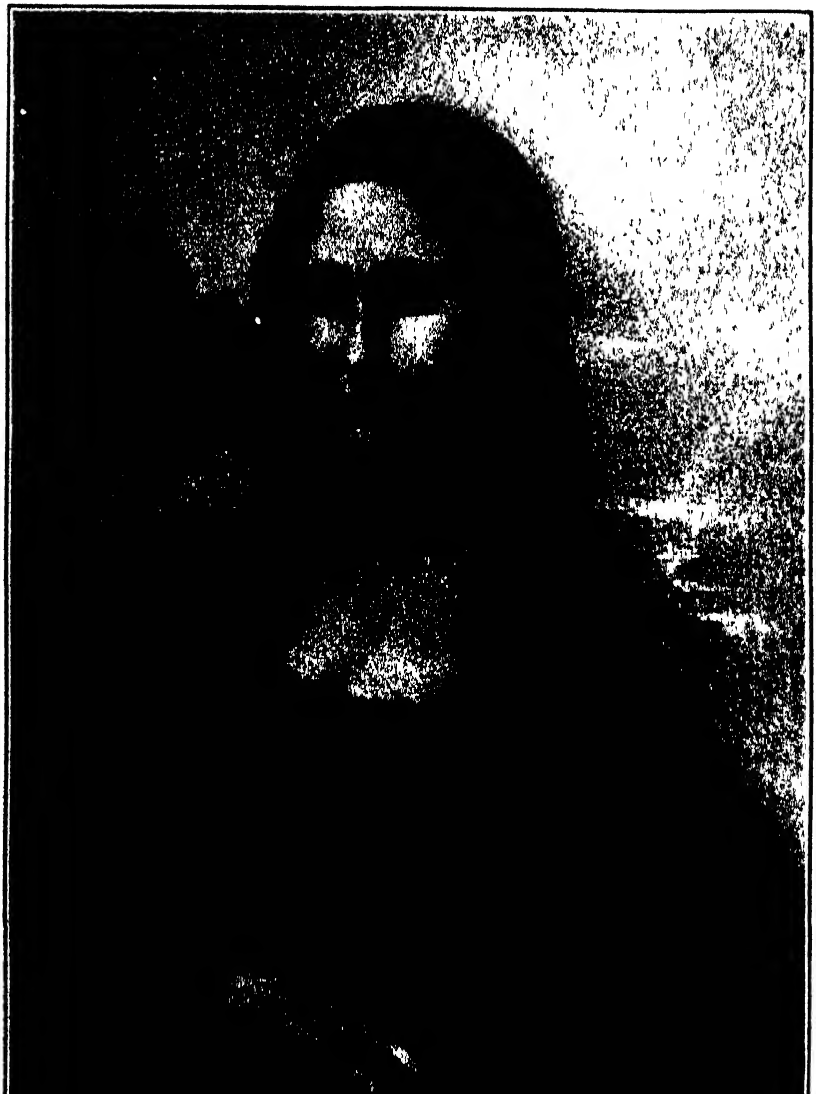
Leonardo devoted his leisure hours to painting and did not hurry. They say that he worked for years on the portrait of "Mona Lisa," never satisfied, seeking something that perhaps he was not himself able to define; this is revealed to us by the mysterious smile and searching look of that woman whose face, after the lapse of four centuries, still reflects to us, like a living mirror, the thoughts of the man who gazed at her with the brush in his hand.

Little is left of his artistic work. Not over four or five pictures can with certainty be attributed to the master's hand; of his sculptures not even one has survived. Fate and the stupidity of man have acted harshly towards his artistic creations; fortunate circumstance instead has miraculously assured his immortal fame by saving his manuscripts, while to us they are the principal proof of his many-sided genius.

Did Leonardo realize this when he wrote the conundrum:

> Feathers shall raise men even as they do birds towards heaven:—That is by letters written with their quills.

[1] See McCurdy, "Leonardo da Vinci's Note Books" and John W. Lieb's paper presented to the Franklin Institute in 1921 from which I have largely drawn for my quotations.



MONA LISA

For briefness sake I must omit Leonardo's treaty on painting, his research work in chemistry and physics and his philosophic considerations; but I can not refrain from quoting his wise counsel to men in public life:

> Words which fail to satisfy the ear of the listener always either fatigue or weary him; and you may often see a sign of this when such listeners are frequently yawning. Consequently, when addressing men whose good opinion you desire, either cut short your speech when you see these signs of impatience, or else change the subject.

In astronomy Leonardo broke his way through and above the crystallized conceptions of his contemporaries and had a clear vision of the truth. Over 150 years before Galileo Galilei was sentenced by the ecclesiastical tribunal for having proclaimed the motion of the earth, Leonardo wrote: "The sun does not move; the earth is a star." To a certain extent he anticipated Newton by pointing out the universality of gravitation not merely on the earth but in the moon also. (Lieb, *op. cit*, p. 23.) The spots on the moon puzzled him, and he says:

> The moon is not luminous in itself . . When all that we can see of the moon is illuminated it gives us its maximum of light, and then from the reflection of the rays of the sun which strike upon it and rebound toward us its ocean throws off less moisture to us.

His eyes strained themselves in trying to detect the nature of the markings on the moon, if he did not precede Galileo in the construction of the telescope, he anticipated him in the desire of magnifying distant images, as appears from a brief sentence jotted in one of his note-books: "Construct glasses to see the moon magnified."

In geology he came very close to the truth by stating that the deluge was not universal but must have been a local inundation; he clearly formulated the transformation to which the continents have been subjected by the phenomena of mountain erosion and sedimentary deposits and from a close analysis of the fossil marine shells came to the conclusion that important geologic upheavals must have taken place in bygone ages.

Leonardo advocated the close study of human anatomy for the sake of art and science and did not hesitate to defy the canons of the church that threw the ban of excommunication on those who practiced dissection of the human body.

He was not deterred, as he says, "by the fear of passing the night hours in the company of these corpses, quartered and flayed and horrible to behold."

> I have dissected more than ten human bodies destroying all the various members, and removing even the very smallest particles of the flesh which surround these veins without causing any effusion of blood other than the

ANATOMICAL DRAWINGS

imperceptible bleeding of the capillary veins . . . and this I repeated twice in order to discover the differences. . . .

And if you say that as the blood becomes thicker it ceases to flow through the veins, this is not true because it continually dies and is renewed.

He gives an accurate description of arteriosclerosis, that is, the hardening of the arteries.

The death of old men, without fever, is caused by the veins, which, going from the spleen of the liver, have their skin become so thick that they close and no longer give passage to the blood which nourishes them The continued flow of blood in his veins causes the veins to become thick and callous so that at last they close and prevent the blood from flowing. An old man, a few hours before his death, told me that he had lived a hundred years and did not feel any bodily ailment other than weakness, and thus while sitting upon a bed in the hospital of Santa Maria Nuova at Florence, without any movement or sign of anything amiss he passed away from his life. And I made an autopsy in order to ascertain the cause of so peaceful a death, and found that it proceeded from weakness through failure of blood and of the artery that feeds the heart and the other lower members which I found to be very parched and shrunk and

MORTAR FOR THROWING BOMBS AND SHRAPNEL

withered; and the result of this autopsy I wrote down very carefully and with great ease, for the body was devoid of either fat or moisture, and these form the chief hindrance to the knowledge of its parts. The other autopsy was on a child of two years, and here I found everything the contrary to what it was in the case of the old man.

Military engineering gave Leonardo a broad field in which to apply his ingenuity and I must limit myself to citing only a few of his inventions.

There is his mortar for throwing bombs and shrapnels that explode in the air; his cylindrical bullets with vanes cut out of the shaft are identical with the darts that were invented at the beginning of the world war to be dropped from aeroplanes to the benefit of the pedestrians He discussed the advantage of rifling cannons and made a drawing of a machine-gun. There would appear (Lieb, *op cit.*, p 41) to be a reference to cartridges in these words:

The mounted carabineers must be provided with slender and simple tubes full of powder, with the ball inside so that they can be readily inserted and in this way an immense number of the enemy will be vanquished, and these carabineers must form in squadrons the same as arbalesters so that one part of them can fire while the other loads, but first be sure to accustom the horses to these noises or better stop up their ears.

One of the most striking statements Leonardo makes is when he refuses to describe the submarine, foreseeing the cruelties and havoc of human lives that would follow if man got into his hands such a treacherous and powerful instrument of destruction:

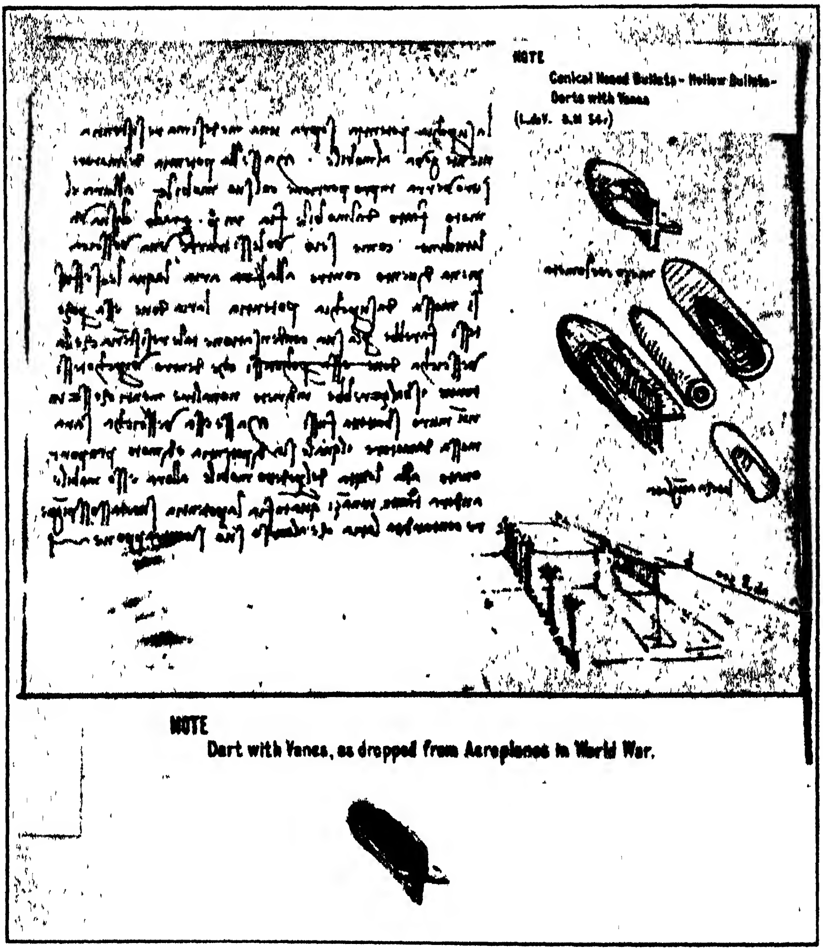
Why is it that I do not describe my method of remaining under water? How long can I stay without eating? These I do not publish or reveal on account of the evil nature of men, who would practice assassination on the bottom of the seas, by breaking the hulls of boats and wrecking them with all on board; while I tell about other means of submergence there is no danger from these because on the surface of the water there appears the mouth of the aspiration tube floating on skins or cork.

For each evil Leonardo sought a remedy; to detect a distant vessel he says:

If you cause your ship to stop, and place the head of a long tube in the water, and place the other extremity to your ear you will hear ships at a great distance from you.

In case of shipwreck he suggests a life preserver as the only safe and efficient device and for this:

It is necessary to have a coat made of leather with a double hem over the breast the width of a finger and double also from the girdle to the knee and let the leather of which it is made be quite air-tight. And when you are obliged to jump into the sea, blow out the lapels of the coat through the hems at the breast and then jump into the sea. And always keep in your mouth the end of the tube through which the air passes into the garment, and if once



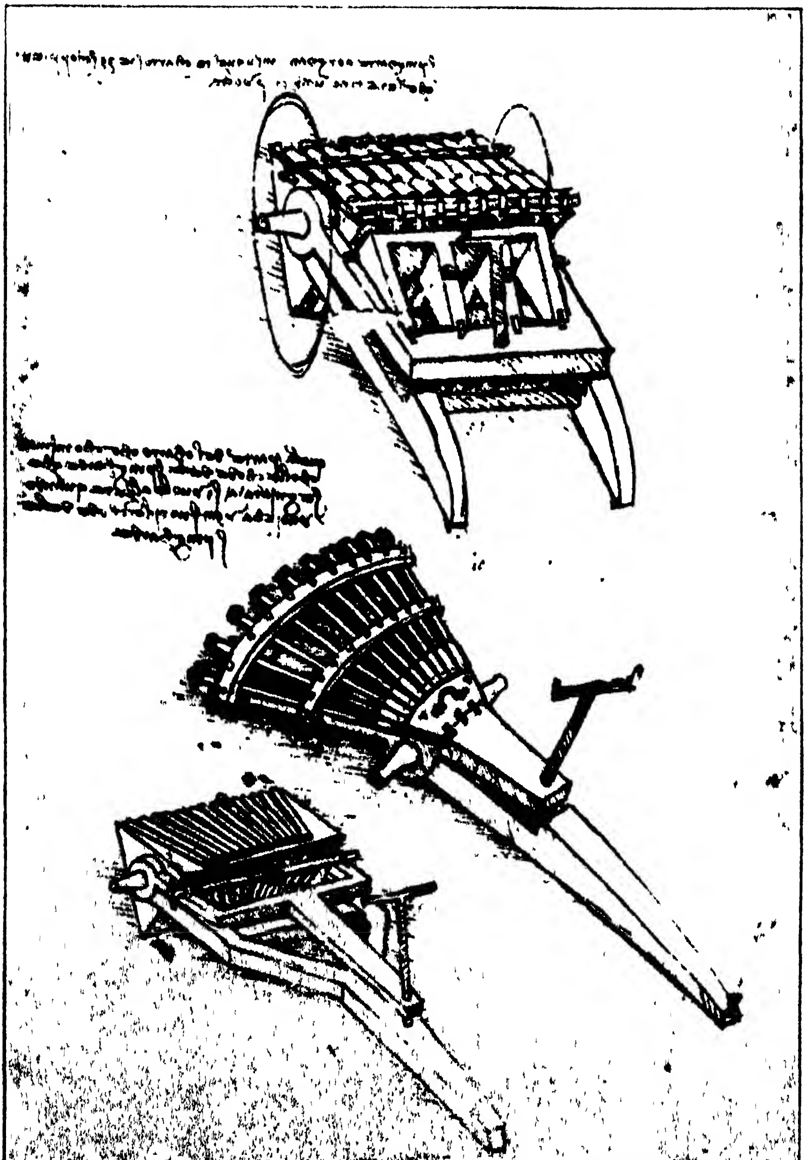
CYLINDRICAL BULLETS WITH VANES CUT OUT OF THE SHAFT

or twice it should become necessary for you to take breath when the spray prevents you, draw it through the mouth of the tube from the air within the coat.

Even the possibility of using poisonous gases did not escape his mind:

Throw among the enemy ships, with small catapults, chalk, pulverized arsenic and verdigris. All who inhale this powder will be asphyxiated by breathing it, but be careful that the wind be such as not to blow back the fumes, or else cover your nose and mouth with a moist cloth so that the powder fumes can not penetrate.

Who would dream that about the time Columbus was first landing in America, there should have lived a man who put into writ-



Drawing of Machine Guns

ing the proper remedy to solve the traffic problem of the city of New York. Leonardo's plan in part has already been carried out by the construction of the elevated and the subway but the humble and harshly persecuted motor-car-dodging pedestrian of New York will some day erect a monument to the Italian engineer only when the city council will have fully carried out Leonardo's plan, which provides that:

> The model cities will be served by two kinds of streets; highways elevated or on a slope, elegantly ornamented and perfectly clean, and lower or subterranean roadways, washed from time to time by limpid water from the watercourse, and from which the refuse will be removed with rakes.
>
> In such a way that whoever wishes to travel by the elevated highway may do so at will; and also whoever wanted to go by the lower route will be free to do so. Vehicles (read motorcars) will never make use of the upper highway, reserved for gentlemen; while in the lower street the wagons and beasts of burden for work and for the supplies of the people will circulate.

Strange and marvelous are these discoveries and inventions of Italy's great genius, but none of his investigations brings him closer to our times and reveals better his absolutely modern methods of gradually and scientifically approaching and analyzing a technical problem than his attempt to solve the problem of human flight.

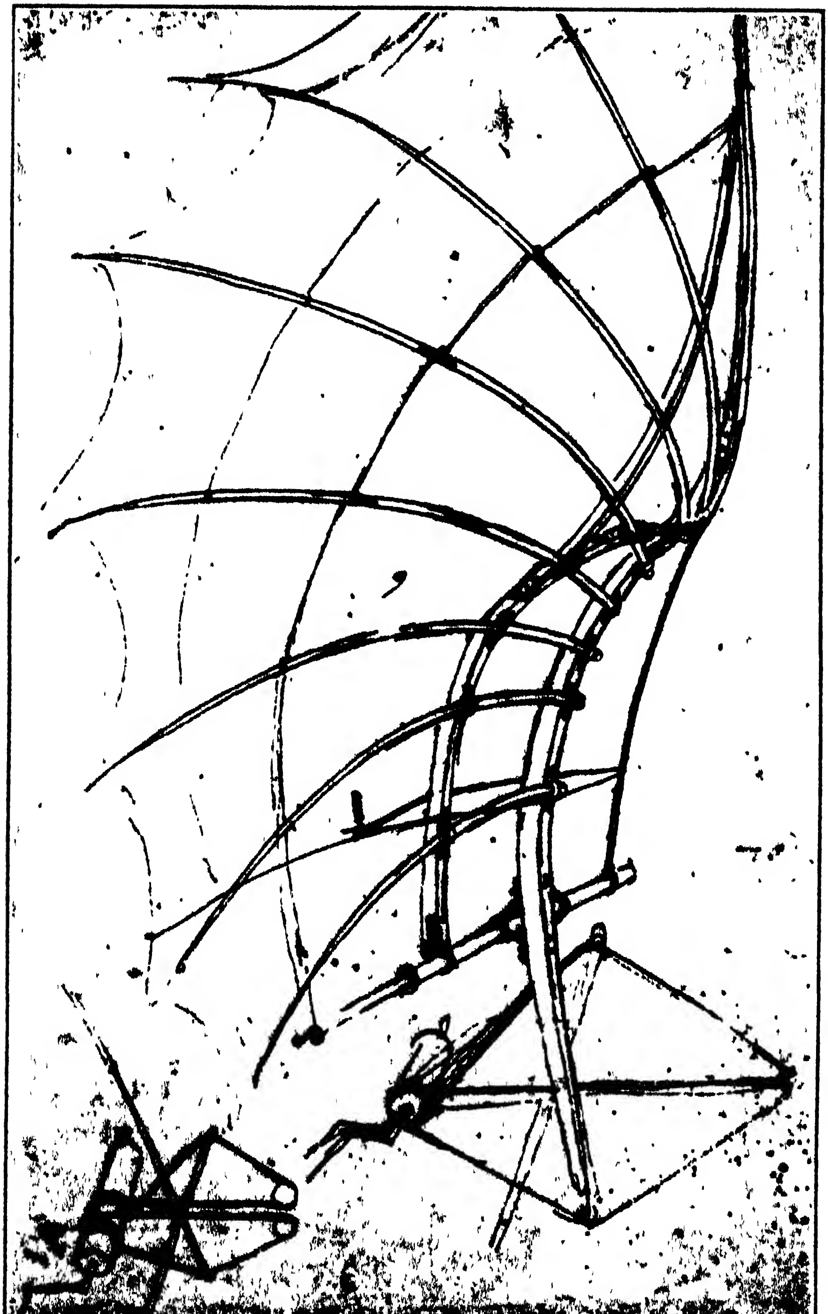
As John W. Lieb says in his paper (*op. cit.*, p. 56):

> Leonardo's pioneer work in the field of aviation would alone entitle him to the highest place as a scientist and engineer, for the science, skill and ingenuity he displayed in his endeavor to solve one of the great problems of the ages, artificial flight, even though he may have achieved no practical results. The record of his work in this field lay dormant and unappreciated for nearly four hundred years, during which the only substantial progress made towards its solution is synthetized in the expression "Lighter than air machines." The full importance of these marvelous records is not recognized by students of aviation problems even to-day, although emphasized by students of Leonardo like McCurdy, Beltrami and others, and they will only reach fruition when attention becomes again concentrated on human flight unaided by external power.

Leonardo approached the problem in the right way, that is, by first studying in minute detail the flight of the birds.

> I have divided the Treatise on Birds into four books; of which the first treats of their flight by beating their wings; the second of flight without beating the wings and with the help of the wind (soaring); the third of flight in general, such as that of birds, bats, fishes, animals and insects; the last, of the mechanism of this movement.

Especially important from our modern point of view is his analysis of the soaring flight, where he clearly defines the principles on which our airplane practice is based. This is how he describes the governing of a soaring flight by the use of the tail rudder and by the warping of the wings, which is Wilbur Wright's principal invention.



SKETCH OF FLYING MACHINE

Therefore we may be certain in the case of those birds which can support themselves above the course of the winds without beating their wings, that a slight movement of wing or tail, which will serve them to enter either below or above the wind, will suffice to present the fall of the said birds.

The helms (rudderlike articulations of the wings) which are on the shoulders of the wings are necessary when the bird in its flight without beating its wings wishes to maintain itself in part of a tract of air, upon which it is either slipping down or rising, and when it wishes to bend either upwards or downwards or to right or left. It then uses these helms in this manner: if the bird wishes to rise it spreads the helms in the opposite direction to the way the wind strikes it; and if to descend it spreads the top part of the helm slanting to the course of the wind. If it turns to the right it spreads the right helm to the wind, and if it turns to the left it spreads the left helm to the wind.

When the bird rises up by the assistance of the wind without beating its wings, it spreads out and raises its wings so that they form an arch with the concave side towards the sky, and it receives the wind under its wings continually, in its movement to and fro . . .

The fundamental element for the flight with motorless gliders that have stirred so much interest in these last two years in Germany and France, that is, a raising air current, is fully explained by Leonardo:

The bird rises to a height in a straight line without beating its wings when the reflex current of the wind strikes it from underneath

The kite and other birds which move their wings only a little way go in search of the current of the wind; and when the wind is blowing at a height they may be seen at a great elevation, but if it is blowing low down, they remain low.

When there is no wind stirring in the air then the kite beats its wings more rapidly in its flight, in such a way that it rises to a height and acquires an impetus, with which impetus, dropping then very gradually, it can travel for a great distance without moving its wings.

After having understood the principles of flight, Leonardo attempted to fly himself. First he tried it out with a little pasteboard model:

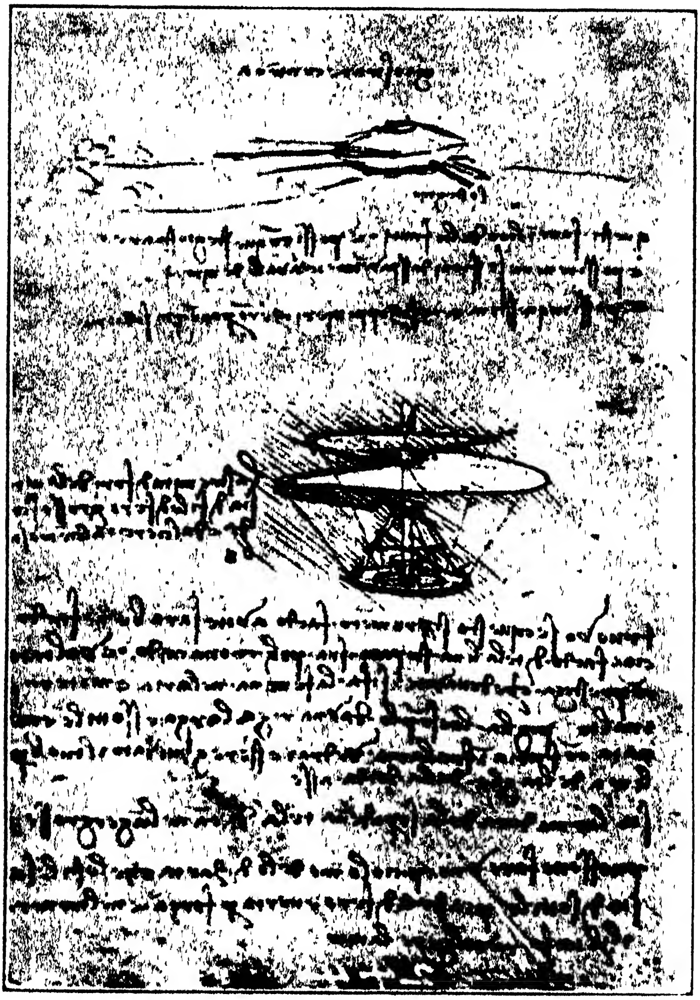
Construct to morrow figures (models) of pasteboard of various forms and make them to descend in the air by dropping them from a bridge; and then draw the curves and the motions which the fall of each makes in various parts of its descent.

He experimented also with the helicopter and the parachute:

If a man has a canopy of water-proof canvas, that is 24 feet on each side and 24 feet high, he can throw himself from any great height without damage to himself.

From these experiments he found out the wise maxim dear to all our modern aviators that:

In testing flying machines do not fly too near the ground, for if you fall you will not have time to right your machine before hitting the ground.



THE HELICOPTER

We have no positive proof that Leonardo actually attempted to fly on an apparatus constructed by himself, though he seems to hint at the intention of doing so when he writes:

> The first flight of the big bird will take place from the lofty Swan Hill (near Florence) and the universe will be filled with its praises and the nest whence it sprang will be filled with eternal glory.

Needless to say that his experiment must have been a failure, judging from what Gerolamo Cardano wrote shortly after his death: "It (the artificial flight) has turned out badly for the two who have recently made a trial of it. Leonardo da Vinci . . . has

attempted to fly but he was not successful." (Lieb, *op. cit.*, p. 60.)

Perhaps this unsuccess prompted him to write:

> Experience is never at fault; it is only our judgment that is in error in promising itself from experience things which are not within her power.

This is, as briefly as can be stated, the story of Leonardo da Vinci's achievements. I do not intend to claim that a unique genius like Leonardo can be taken as an illustrative example of the Italian race; but nobody can affirm that his genius was a mere fluke because the Italian generations that preceded and followed him gave birth to hundreds of men who ranked a close second to him. But Leonardo's achievements emphasize the statement made at the beginning of this article, that is, that the Italian mind has essentially a scientific and technical trend to which the artistic temperament of the people has given an expression of unparalleled beauty.

The scientific and technical tendency of the Italian people remained unimpaired even when the wonderful flowering of the Renaissance came to an end It would astonish more than one American to hear the leading part that sunny Italy has had in the development of modern astronomy, anatomy, physics, chemistry, electricity and mathematics.

America is the land of technical achievements; to these Italy has silently contributed with the power of her intellect, and she is more proud of this than of the achievements of Christopher Columbus and Amerigo Vespucci.

THE MOTIONS OF THE STARS AND THE EXISTENCE OF A VELOCITY-RESTRICTION IN A UNIVERSAL WORLD-FRAME

By Dr. GUSTAF STRÖMBERG

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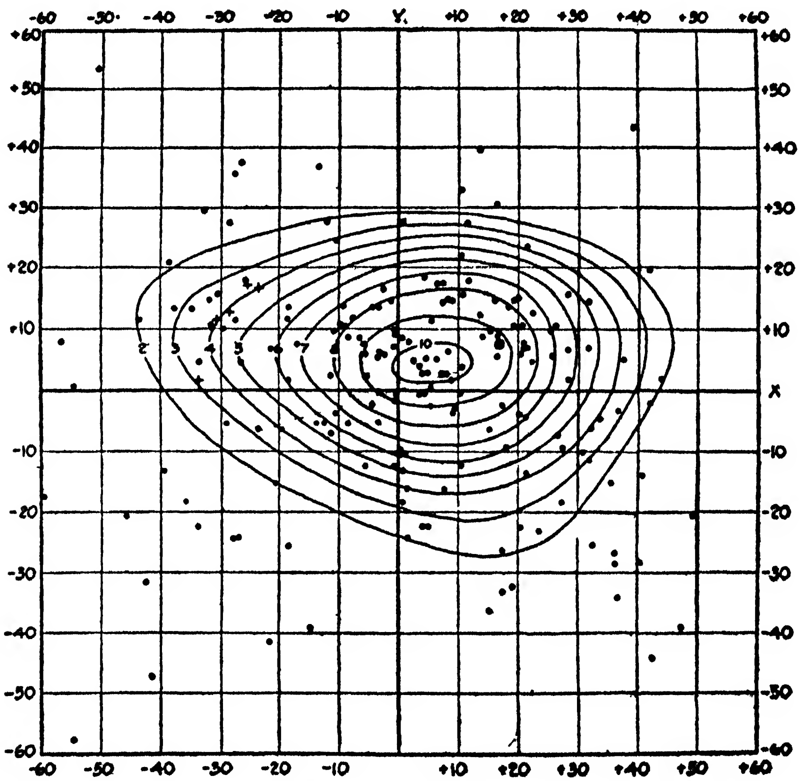
Our knowledge of the motions of the stars has increased considerably during the last decade. This has mainly been due to the determinations of radial velocities of a wide variety of objects and to the fact that stellar distances have been determined with a higher precision than has formerly been possible, particularly through the greatly increased accuracy in the determination of trigonometric stellar parallaxes and the application of the spectroscopic method of deriving the absolute magnitude of stars. The knowledge of the distances of individual stars makes it possible to determine the three velocity-components of the stars from their radial velocities, proper motions and distances. The most important results of these investigations are the confirmation of the ellipsoidal theory for the distribution of stellar velocities and the discovery of an asymmetry in the velocity-distribution, having a remarkable generality and regularity, which may be of importance for our conceptions of the properties of interstellar space.

The Distribution of Stellar Velocities

The ellipsoidal theory was introduced by Schwarzschild in 1908 as an alternative to the "two-stream" theory of Kapteyn. These two theories represent the distribution of stellar velocities by using two different frequency-functions. To obtain a general idea of what is meant by a velocity-distribution we will suppose that we have computed the three velocity-components for a number of stars in a certain system of coordinates, referred to the sun as origin. Imagine now a number of points all starting at the same moment from a common origin, each moving with a velocity parallel to and equal to that of one of the stars. After moving for one second they are all stopped; the points then form a cluster, the "velocity-cluster." The configuration of these points represents the distribution of velocities among the stars studied. In order to describe this cluster we will compare it with a body having a variable density, *e.g.*, a gas, called the "velocity-body," whose density represents the number of points per unit of volume. This density is proportional to the probability that all three velocity-components fall

within certain limits, or that a velocity-vector terminates in a definite volume of "velocity-space." The density in the velocity-cluster varies rather irregularly, especially if the number of stars is small, but we will suppose that within the ideal velocity-body it varies continuously from point to point. This variation in density is represented mathematically by a "frequency-function" or "distribution-law."

In a study of the motions of the stars of spectral classes F, G, K and M, made at the Mount Wilson Observatory two years ago,[1] a trigonometric series was used to represent the density in the velocity-body, and the result for giant stars of solar type (G6 to K1)



G6 to K1; M ≦ 3.9

FIG. 1a. Velocity-distribution for giant stars of spectral types G6 to K1. The dots represent the velocities of individual stars, and a line from the origin to a dot gives, in direction and amount, the velocity of a star projected on the galactic plane. The sun is marked by a point within a small circle. The closed curves represent intersections of surfaces of equal density with the plane of projection.

[1] Mt. Wilson Contrib., No. 245, *Astrophysical Journal*, *56*, 265, 1922.

is shown graphically in Fig. 1a and b. The coordinate-system used is the galactic system, with the xy-plane coinciding with the great circle of the galaxy. The x-axis is directed towards the intersection of the galaxy and the celestial equator (in Aquila), the y-axis is in 90° galactic longitude, and the z-axis points towards that pole of the galaxy which is in the northern hemisphere. Surfaces of equal density (equifrequential surfaces) have been computed, and the intersections of these surfaces with the xy- and the xz-plane are the closed curves shown in the figures. The dots represent individual stars, and the line from the origin to a dot indicates, in direction and amount, the velocity of a star projected on the xy-plane in one figure, and on the xz-plane in the other. Only those dots are indicated whose lateral distances from the two planes of projection are small. As the sun itself is a star, wholly comparable with other stars in so far as its motion is concerned, we have not

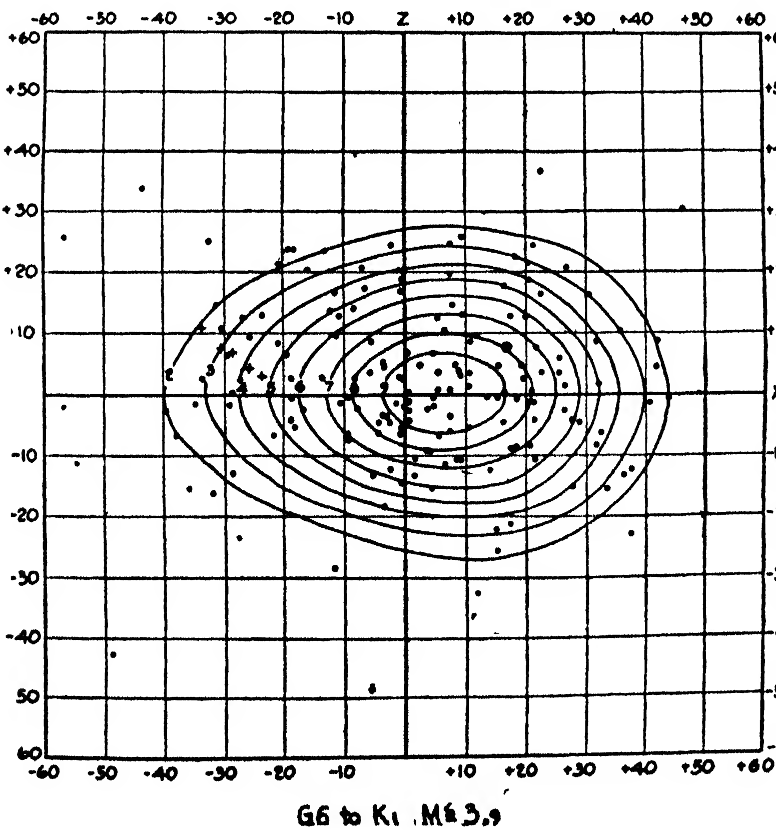


FIG. 1b. Same as Fig. 1a, but the plane of projection is here perpendicular to the galactic plane.

used in these figures the sun as origin, but have taken an algebraic mean of the three coordinates as origin. The velocity of the sun relative to the adopted origin is 20 km/sec. towards the point in the sky whose right ascension is 270° and declination + 30°. This is what we ordinarily refer to as the sun's velocity relative to the stars. The point which represents the sun in the two figures is indicated by a dot within a small circle.

From the diagram we see that the intersections between the equi-frequential surfaces and the xy- and xz-planes are in general elongated, closed curves, the elongation being along an axis which nearly coincides with the x-axis. The surfaces of equal frequencies are consequently not spherical, but elongated. If the equi-frequential surfaces had been concentric spheres, this would have indicated that the probability of a velocity, if referred to the center of the sphere, was independent of the direction of motion and dependent only on its size.

In Schwarzschild's distribution-law the dispersion is different along different axes and the distribution is characterized by an ellipsoid, the velocity-ellipsoid, the principal axes of which give the direction and amount of the maximum and minimum values of the dispersion. This velocity-ellipsoid corresponds to one of the equi-frequential surfaces.

According to the two-stream theory of Kapteyn there exist two interpenetrating groups of stars, the velocity-distribution within each one being represented by a spherical distribution-law. Were this hypothesis applicable we should expect to find two points around which the velocities would cluster, and the surfaces of equal frequency would either surround them separately or, in the case of the outer surfaces, surround them both. This, however, is not the case, as can be seen in Fig 1. We have, instead, for the F, G, K and M stars at least, a single center and a configuration resembling that of the ellipsoidal theory of Schwarzschild. The major axis, however, coincides in direction with the line joining the two centers in Kapteyn's representation.

The study of the space-velocities of stars of spectral type A indicates the existence of three groups of stars, of which the most numerous, the "central group," has the same velocity-distribution as the F stars of high luminosity.[2] The other two groups, which, however, are not numerous, are identical with the Taurus and the Ursa Major groups, respectively; but can also be identified with Kapteyn's first and second streams, although these two streams have in general gone over into the ellipsoidal distribution.

The superiority of the ellipsoidal theory was first shown by Charlier in 1913. But several marked differences between the ob-

[2] Mt. Wilson Contrib., No. 257, *Astrophysical Journal*, 57, 77, 1923.

served and the calculated distribution were found, which indicated an inherent skewness, on the one hand, and an excess of large linear velocities, on the other. A further study of space-velocities has confirmed these deviations and has led to very remarkable results.

As seen in Fig. 1a the curves of equal frequencies are not symmetrical around the origin, the point of highest density lies in the first (upper right hand) quadrant of the xy-plane. This property has been found to be common to all giant stars, and shows that the mean of the x-, y- and z-coordinates is not identical with the most frequent values of these coordinates, as would be the case for a symmetrical distribution. This asymmetry can perhaps be best visualized by an inspection of the dots in Fig. 1a The outlying dots do not form a symmetrical distribution around the condensation point, but show a marked tendency to avoid the first quadrant of the xy-plane. This asymmetry is especially marked if we limit ourselves to stars of high velocity. Fig. 2 represents the velocities higher than 100 km/sec. referred to the adopted origin. A line from the origin to a dot represents, in direction and amount, the velocity of such a star projected on the galactic plane. The velocities perpendicular to the xy-plane are fairly small and irregular, but the velocities in this plane show a marked asymmetry. Counting galactic longitudes from the positive x-axes (0°) over the positive y-axis (90°), we find that the points all lie between galactic longitudes 143° and

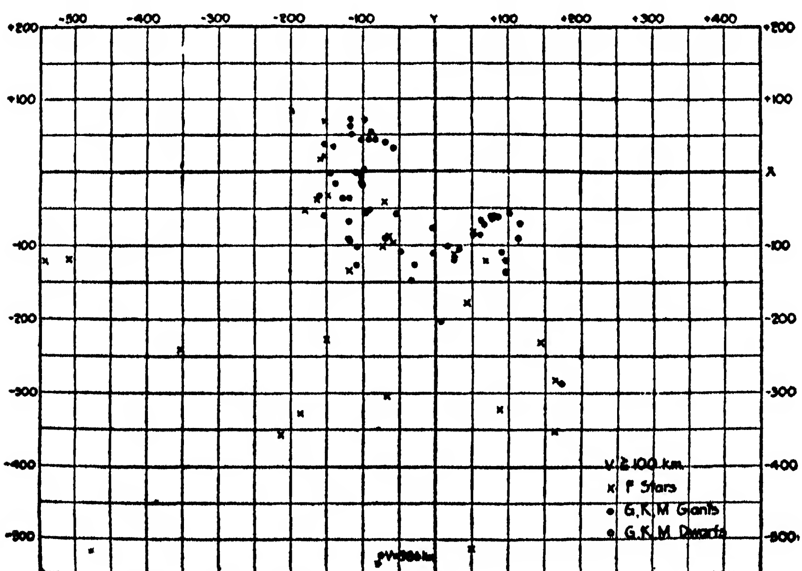


FIG. 2. Distribution of velocities higher than 100 km/sec. A line from the origin to a dot represents such a velocity projected on the galactic plane.

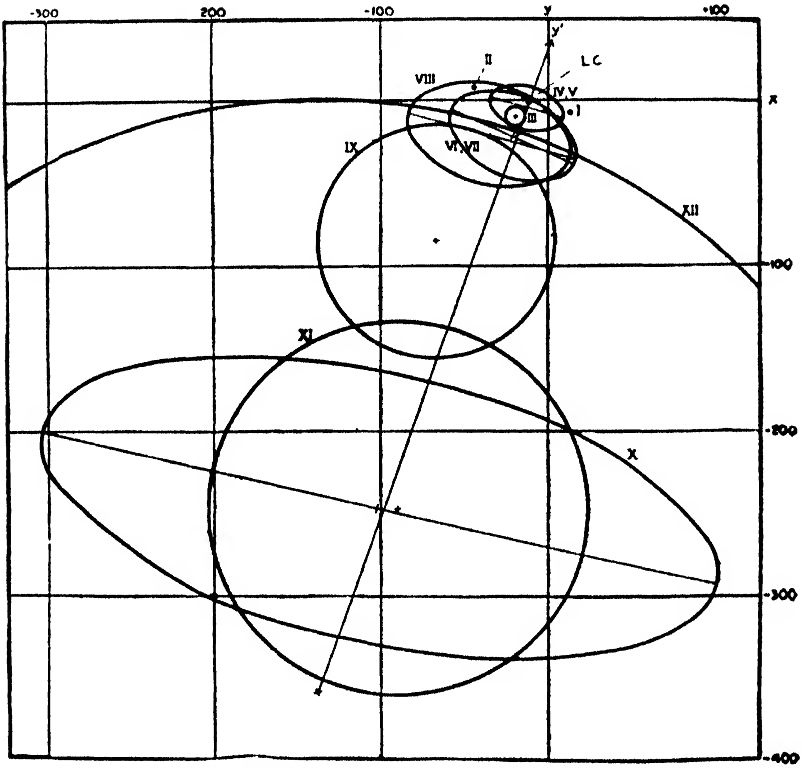


FIG. 3. Projection of the velocity-ellipsoids for different classes of stars and nebulae on the galactic plane. The sun is at the origin and the line from the origin to the center of an ellipse or circle represents the group-motion, relative to the sun, of that particular class of objects. The axes of the ellipses are equal to the dispersion in velocity within the groups. The systematic change in group-motion with increasing internal dispersion can be clearly seen. The line marked y′ represents the direction of translation of objects with small divergence in motion relative to objects of large divergence.

334°, and that not a single one falls in the interval of longitude 334° to 143°, in other words, nearly all stars move towards the same hemisphere.

This asymmetry, which was first established by B. Boss, has recently been studied at the Mount Wilson Observatory,[8] and, with a certain reservation for the B-stars, has been found to be a very general phenomenon, existing among all classes of stars, and even among the distant star-clusters and spiral nebulae. Fig. 3 shows the results for a great variety of objects, with enormous differences in motion. The sun is now placed at the origin, and the line from the origin to the center of an ellipse or circle represents the group-motion, relative to the sun, of a particular class of objects, projected

[8] Mt. Wilson Contrib., No. 275, *Astrophysical Journal, 59,* 228, 1924.

on the galactic plane. The principal axes of the ellipses represent, in direction and amount, the maximum and minimum values of the internal dispersion. If the dispersion is the same in all directions, or if the observations are insufficient to determine differences in dispersion, the velocity-figure goes over into a circle whose radius is equal to the mean value of the dispersion. Groups I and II are the Ursa Major and the Taurus groups, respectively, each one of which consisting of stars moving almost parallel to one another and within which the dispersion consequently is almost zero, so that the corresponding circles are very small. Group III consists of the B-stars; IV is the central group among the A-stars; V and VI are stars of spectral types F, G, K and M, the velocities of which are represented by two ellipsoidal distributions. The majority of stars in group V are giants, in group VI dwarfs; but, as the asymmetry exists for both these classes of stars separately, it was found advisable to represent the whole collection of objects by two distribution-laws. Group VII includes nebulae whose spectra show bright lines; and VIII, variable stars with bright-line spectra, the period of light variation being fairly long for these stars. Group IX is composed of variable stars with periods less than one day, the so-called cluster-type variables; X, of stars with excessively large velocities; XI consists of the globular star-clusters, and XII are nebulae with continuous spectra, most of which have spiral structure. The velocity-ellipsoids for the groups VII, IX, XI and XII are determined from the radial velocities, without the use of proper motions. The ellipsoids for groups IV and V on the one hand, and groups VI and VII on the other, are so nearly alike that they have been combined in order not to confuse the diagram.

We see clearly how the centers of the ellipses are shifted towards the third (lower left hand) quadrant as the internal dispersion increases. This means that the groups, regarded as units, move in a certain direction with a velocity dependent upon the divergence in motion of the stars within the group. The asymmetry in stellar motions is thus a phenomenon of great generality, and its explanation must be of fundamental importance for our conception of the mechanical laws which govern the motions of the stars. The ellipsoidal nature of the velocity-distribution, or what we usually call stream- or preferential-motion, is ordinarily explained as a result of the fact that the sun is not at the center of gravity of our local system, but removed from it, and that a preponderance of the stars move around this center.

A closer study of the distribution of velocities for the different classes of objects has shown that the relation between group-motion and the dispersion along the axis parallel to the systematic displace-

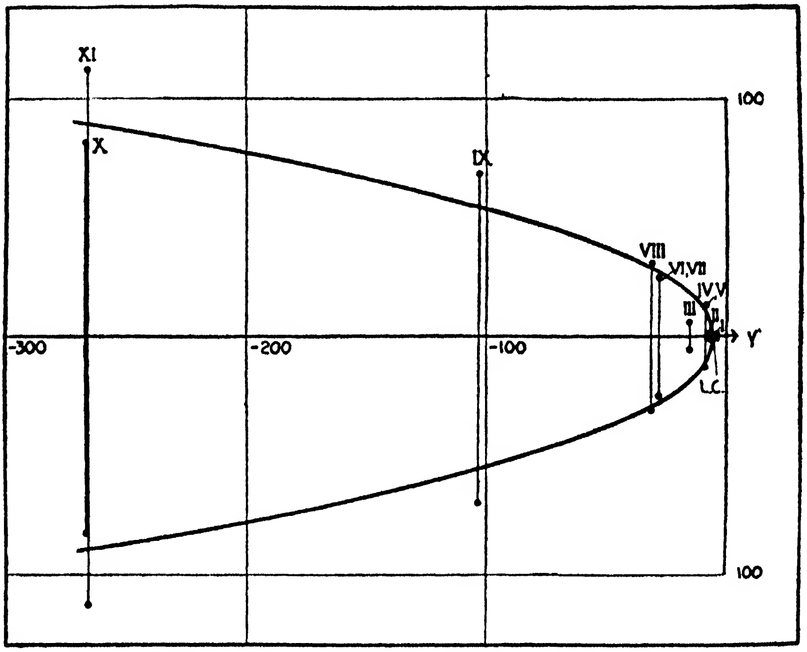


FIG. 4. Relation between systematic change in group-motion (abscissae) and dispersion along an axis parallel to this systematic shift (ordinates). This relation is represented by a parabola with its axis along the line of systematic displacements.

ment is very definite. This relation is graphically represented in Fig. 4 by a parabola, whose axis is parallel to the systematic displacement, the points in the figure indicating the agreement for the individual groups. Except for the B-stars (group III) the agreement is surprisingly good. An important fact is that the condensation-point in the velocity-distribution of stars of types F, G, K and M nearly coincides with the apex of the parabola, which represents the group-motion of stars of vanishing internal dispersion. This point is marked L. C. (limiting center) in Figures 3 and 4.

The existence of this relation between group-motion and dispersion leads to remarkable consequences. The velocity-distribution for all the cosmical objects studied can now be represented by a product of two frequency-functions, both symmetrical, but with different centers of symmetry. One of these centers corresponds to the top of the parabola, and the velocity of the sun relative to this point is 14 km/sec. towards the point in the sky $\alpha = 262°$, $\delta = +15°$. The opposite vector represents, in a certain sense, the most frequent stellar velocity. The velocity of the sun relative to the center of the second distribution, about 300 to 400 km./sec. in the direction

$\alpha = 323°$, $\delta = +60°$, is the same as its velocity relative to stars of maximum velocity, as well as its velocity relative to distant objects; these two latter velocities seem to be identical.

It has been known for some time that the velocity of the sun is different when referred to stars of different spectral types; and also when referred to stars of different apparent magnitudes. The sun's apex has a higher declination for stars of later spectral types and for stars of fainter apparent magnitudes than for earlier spectral types and brighter stars. Now it is known that stars of high intrinsic brightness and of early spectral types have the smallest peculiar motions. Since apparently faint stars are in general intrinsically fainter than the apparently bright stars, we see that the shift of the sun's apex is another aspect of the asymmetry, and that the limiting positions of the apex are nothing but the apices as referred to the two centers just mentioned.

We can explain the existence of two fundamental frequency-functions in the following way. If there is a fundamental system of reference in space of such a nature that very great velocities referred to this system are less frequent than smaller velocities, so that a "velocity-restriction" exists in this fundamental system, the effect on the motions in our local system of stars would be just that observed.

A simple example may help to illustrate the effect of such a velocity-restriction. Imagine a ship moving forward with great speed so that a strong headwind is blowing. On shipboard are several classes of individuals, all similarly affected by the wind, but having contact with the ship of different degrees of strength. We have then to do with two connections or velocity-restrictions acting at the same time on the different individuals, one limiting their velocities relative to the ship the other relative to the air. The first connection is represented by a velocity-distribution with its center attached to the ship; the center of the second distribution is at rest in the air. The members of the first group are supposed to be intimately connected with the ship and can move only very slowly relative to it; as a whole this group follows the ship in its motion. A second group consists of individuals who can move with greater freedom relative to the ship and consequently have a greater velocity-dispersion. Members of this class move faster towards the stern than towards the bow, and, if they do not take care, they may be blown off the ship entirely. The members of a third group have almost completely lost contact with the ship, or have contact only part of the time (*e.g.*, sea gulls); they can move fast in all directions and after a while form a group having a large velocity-dispersion, which, as a whole, is nearly at rest in the

air. A fourth group consists of other ships moving at random in all directions relative to the atmosphere. They have great velocity-dispersion and nearly the same group-motion as the third group. The velocities of these four groups can be represented by a series of velocity-distributions, whose centers are shifted in a certain direction, dependent upon the internal dispersion.

We see easily that all these groups are represented in our study of stellar motions. The relation between group-motion and dispersion which we have found, and which is represented by the parabola in Fig. 4, can be shown to be a necessary consequence of the combined effect of two connections or distribution-laws. One of these distributions is the velocity-distribution in the local system of stars, when no external velocity-restriction is acting; the other can be thought of as a "bond" between the individual stars and a cosmic system in which the globular clusters and spiral nebulae appear to be at rest in a statistical sense. In the following we will call this larger system the "world-frame" The first distribution probably represents an effect due to the fact that the stars in our local system have a common origin, with certain reservations, however, for the Ursa Major and the Taurus groups and the B-stars, which seem to form moving systems within the local system. As to the significance of the second connection we are more in doubt. In the following section we will discuss different explanations for the existence of this connection between the stars and the world-frame.

The Stars and the World-frame

We may imagine that the world-frame consists of a great field of stars, star-clusters and nebulae with respect to which our local system of stars has a velocity of about 300 km/sec. towards a point in the sky not far from the north pole of the ecliptic. It has been suggested that the proportion of stars belonging to the different types in the local system and in the world-frame changes steadily as we pass from group I to XII, and that, when we reach the three last groups in our series, we are dealing exclusively with objects belonging to the larger system. This hypothesis contains rather arbitrary assumptions and we should in this case expect to find a more marked change at the transition from one system to the other. Another possibility is that the different groups studied have originated in systems of different sizes and different motions relative to each other, the larger system giving rise to stars of higher relative velocities than those of smaller size. It seems difficult to reconcile the existence of a very *regular sequence* of groups with this hypothesis.

When stars belonging to two interpenetrating systems come near one another their mutual attractions influence their orbits, and the

ultimate effect of such encounters is that the dispersion perpendicular to the relative motion of the two systems is increased, while the translation is decreased in proportion to the increase in dispersion. It is remarkable, and it may not be accidental, that the stream-motion (major axis of the velocity-ellipsoids) is nearly perpendicular to the translation of the local system relative to the world-frame. On the other hand, however, the number of stars per unit of volume belonging to the larger system must be exceedingly small, and it seems almost impossible that the effect of encounters should have any appreciable effect at all. The conception of an enormous field of stars and nebulae seems to presuppose the existence of an organic connection between its parts, and this leads to the question: Why do not cosmic velocities exist that approach the velocity of light? The largest radial velocity as measured by Slipher is 1800 km/sec. (N. G. C. 584) and the transverse velocities probably do not exceed this value, provided we use an *inertial system* as reference-system for the proper motions.

If all cosmic objects have originated from the same system of gas or dust, we may imagine that some distribution of kinetic energy has taken place before the formation of the stars, and that consequently the velocity of a star, relative to the system as a whole, must be limited. We have reason to believe that the stars in our local system have a common origin, or have originated in several systems with fairly small velocities relative to one another. It has been found by Halm, and more recently by Seares, that there is strong indication of an equipartition of kinetic energy for the internal motions of certain classes of objects in our system. This can hardly be explained as an effect of encounters between stars, and seems to be due to initial conditions. Whether the remaining objects, including the most distant, have been included in this original system, or whether their motions have been affected by any distribution of kinetic energy before or after their formation, we do not know; but it is worthy of consideration that the distribution of velocities in the world-frame does not correspond to an equipartition of energy, for the individual velocities referred to the larger frame seem to be independent of mass. In fact, if we compute the mean velocity (in three dimensions) for the stars belonging to each of groups I to XI and refer these velocities to the world-frame, we find that they are all very nearly the same, namely about 300 km/sec; but the masses of the stars in the different groups vary considerably. This velocity may thus, in a certain sense be regarded as the mean "absolute" velocity of a star, even of those in the distant globular clusters. The mean velocity of the spiral nebulae referred to the same frame is about 600 km/sec, provided we have

the right to apply a systematic correction to the wave-lengths corresponding to an outward motion of about 700 km/sec.

In order to explain the absence of excessive cosmic velocities Einstein has assumed that the space-dimensions are curved, while the time-dimension is not curved, so that, for measurements on a cosmical scale, space is finite but unbounded. The inertial lines as well as the optical lines are closed curves. This leads to the conception of a fundamental system of space-coordinates in which all the matter in the universe is permanently at rest in a statistical sense This assumption is, to a certain extent, a contradiction of the fundamental principles of the theory of relativity, but Einstein starts from the assumption that the metrical properties of space are *completely* determined by matter in space. It is thus conceivable that a coordinate-system in which the material universe is at rest has fundamental properties. Several scientists, among them the most ardent advocates of relativity, have expressed strong doubts that the fundamental metrical properties of space, such as the phenomena of inertia and the propagation of light, are *completely* dependent upon matter and gravitational fields, and that consequently these properties would be lost if the stars could be annihilated. If we follow Einstein we must assume, for instance, that the vibration-plane of Foucault's pendulum is held in position by the stars,[4] or their gravitational field; that a flywheel is torn to pieces by an action of the stars; that the nodes and loops of an electromagnetic wave are held in position by the stars (and consequently do not follow the earth in its rotation[5]); that the path of a beam of light is not only deflected by passing near a star, but that the very possibility of light propagation is dependent upon the existence of the stars.

If we assume, however, that space or space-time has fundamental properties independent of the existence of the stars, and that these properties are only modified in the neighborhood of matter (which modification can be regarded as equivalent to a gravitational field), many of the difficulties disappear. The three-dimensional nature of space and of solid bodies, the one-dimensional nature of time, the constant velocity of light and the existence of inertia can be regarded as such fundamental metrical properties.[6] The limitation of cosmical velocities may possibly be connected with a fundamental property of space, which prevents the material cosmic system from "evaporating," and gives the stellar frame a certain degree of

[4] The "stars" mean here and in the following the sum total of all matter in the universe.

[5] An experiment to test this has been suggested by Silberstein and is now being performed by Michelson and Gale.

[6] Even a curvature of space and time has been regarded by De Sitter as an absolute property independent of the matter in the universe.

rigidity. The coincidence, so far as rotation is concerned, between the stellar frame and the inertial frame is a necessary consequence of such a velocity-restriction.

These considerations call our attention to the classical conception of the ether as a space-filling medium, giving space its electromagnetic properties. The theory of relativity does not compel us to deny the existence of such a medium; on the contrary, the four-dimensional space-time has been identified by Einstein with the ether, which he regards as necessary in order to understand the existence of "absolute" rotation and acceleration. We quote Einstein's words in his Leiden Lecture of 1920:[7]

> Newton might no less well have called his absolute space ether; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked upon as real, to enable acceleration or rotation to be looked upon as something real.

The reference-frame for "absolute" acceleration or rotation can be called "ether" or "space-time," or a "field of geodesics" (Eddington), or the "metrical field of space" (Weyl), and it can be "materialized" by light rays or moving particles ("world-lines"). The earth rotates relative to a metrical field, in which the stars are nearly at rest in a certain sense, which is the same as Newton's conception. On account of the existence of this metrical field the earth's motion around the sun and the sun's motion around the earth are not equivalent, as evidenced by stellar aberration, stellar parallaxes, and the yearly variation in the radial velocities of *all* the stars, which phenomena do not exist for an observer on the sun, or rather at the center of mass of the solar system. Weyl[8] has pointed out that without this metrical field, the conception of one body moving relatively to another body, separated from the first, would be entirely meaningless. The remarkable thing is that this metrical field is ambiguous with regard to uniform motion of translation.

An interesting analogy has been pointed out by Einstein in the lecture just quoted. When we study waves on the surface of the water, it is the propagation of the waves which we observe, and not the motions of the water-particles themselves. If the existence of floats in the water were a physical impossibility, we would have no means whatever of studying the motions in the water, and our description of the motion would be of such a form that the motion of the individual particles does not enter into it. The nearest approach to observable floats, moving with the least dependence on one another, seems to be the stars, which can be regarded

[7] "Ether and the Theory of Relativity," Sidelights on Relativity, Methuen, 1922.

[8] "Massenträgheit und Kosmos," *Die Naturwissenschaften, 12,* 197, 1924.

as influenced by a number of impulses. Prominent among these impulses are the gravitational forces, but there may be others; and even the most feeble impulse, if acting in the same direction during billions of years, may have an effect upon the motion, and we can thus regard the stars as indicators, extremely sensitive for secular effects. We can not study a star during any very long time, but we can study the present velocity-distribution, and we can make assumptions about the original distribution. The study of stellar motions indicates that space, or something in space, has the property of exercising a restricting influence on stellar velocities relative to a system of coordinates that seems to be the same everywhere, *i.e.*, it is stationary. The mechanism of this restriction is unknown, but the asymmetry in stellar motions indicates that it is a gradual process. It seems possible that there exists some sort of reaction during the process of radiation, when the connection between an electron and the ether is of another and more intimate nature than when the electron is not radiating. In the latter case the conception of absolute motion seems to be meaningless, but we can not be quite sure that this is the case for a radiating electron.

At all events, if there exists a space-filling medium we should expect to find some effects of it on stellar motions, even if these effects are entirely too small to be noticeable in laboratory experiments. The existence of a fundamental velocity-vector, as that defined by the asymmetry in the velocity-distribution, points to a property which can be most simply explained as a translation relative to a fundamental and universal system of reference. That this velocity-vector agrees with the translation of our sun relative to very distant objects, at least in so far as it is possible to determine this translation from the present data, gives additional justification for this interpretation.

We can express this in another way. When we refer the motion of a body to systems of larger and larger dimensions, we find that we have to stop at the system of clusters and spirals, not only for the reason that we can not observe more distant objects, but also for the reason that this cosmical system seems to have certain physical properties and not merely statistical qualities.

PARASITISM AMONG THE INSECTS

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Among the insects, parasitism may be considered either a widespread and, indeed, fundamental habit of life or a comparatively rare and recently acquired one, depending on our viewpoint. It is evident at the start, then, that before proceeding to discuss insects as parasites we must determine just what limits our subject shall have.

As a generally accepted definition of a parasite we may take that of Braun, translated as follows by Fantham, Stephens and Theobald: "Parasites are living organisms which, for the purpose of procuring food, take up their abode, temporarily or permanently, on or within other living organisms." Essentially the same idea, with one valuable addition, is expressed in Webster's Dictionary: "Parasite—a living organism which lives on, in or with some other living organism from which it derives nourishment."

One further quotation from Fantham, Stephens and Theobald is perhaps germane to our discussion, since it shows more clearly just how Braun himself interpreted his definition: "Occasional parasites, such as the flea, the bedbug, the leech and others, only seek their host to obtain nourishment and find shelter while thus occupied."

Our usual idea of a parasite, then, may be summed up in the following five statements, of which the first two are essential characteristics of all parasites, while the last three are of secondary importance and, as we shall see later, do not hold true for all parasitic forms.

A Parasite *always*—

(1) lives on, in or with some other living organism.

(2) derives its food from this other living organism, which we call its host.

As a rule, a parasite also—

(3) is smaller and weaker than its host.

(4) does no serious injury to its host (in the case of True Parasites only).

(5) often shows ("degenerate") structural adaptations for its parasitic mode of life.

As far as the insects are concerned, the two essential characteristics may be somewhat amplified. In the first place, a parasite lives on, in or with its host, and may do either *permanently*, like

the lice, which even glue their eggs to the hair or feathers of their host, or *temporarily,* like the bot-fly, whose larva lives in the stomach of a horse, but which pupates in the ground and has a free-living adult stage, or like the flea, which visits its host periodically for blood as an adult and may even spend much of its adult life on the host's body, while its larval stages live happily on in dust and débris whether the host is near at hand or far away. Or, finally, a parasite may live on its host only *occasionally,* like the mosquito, which visits the host only for the brief period necessary to obtain a meal of blood.

At first sight, I admit, it seems far-fetched to consider a mosquito as a parasite. But where are we to draw the line? Consider such a series of insects as this:

(1) A wood mosquito (*Aedes*), which will feed on blood when opportunity offers, but is entirely capable of completing its life cycle without it.

(2) A malaria mosquito (*Anopheles*), which visits houses to obtain blood and is unable to develop eggs without it.

(3) A yellow fever mosquito (*Stegomyia*), which not only visits houses for blood, but lives and breeds in and around houses, as well.

(4) A bedbug, which lives and breeds in houses, visits human beings for blood, and shows degeneration of its wings.

(5) A flea, which breeds in houses (or in the nest of its host), has lost its wings, which visits the host for blood and may remain on the host longer than is necessary for feeding alone.

(6) An ordinary louse-fly (*Hippobosca,* for example), which normally lives on the body of its host and feeds on its blood, but retains well-developed wings and occasionally leaves the host for a flight through the air.

(7) A wingless louse-fly (such as the "sheep tick," *Melophagus*), which always lives and feeds on the body of its host, just as a louse does.

Where, in such a series as this, can we draw a sharp line and say, "Here the parasitic mode of life begins?" Or, to take another example, who would deny the name of parasite to a tick? Yet the majority of ticks do exactly what a mosquito does, that is, they visit their hosts only for a period necessary to obtain a meal of blood. The only difference is that while the mosquito is able to engorge completely in a few minutes, the tick may require days or even weeks. But when engorgement is complete, off drops the tick, and proceeds to digest the blood-meal and either moult or lay its eggs in a strictly free-living condition.

To cut a long argument short, to me, at least, the most logical and expedient way of deciding the question seems to be to include even the extreme cases under the general heading of parasites.

In the second place, a parasite derives its food from its host. I do not wish to become entangled in a discussion of symbiosis, commensalism, and so on, because most of the cases classed under these and other heads have been so imperfectly investigated that one who

argues for or against their existence is too often driven to rely on imagination in lieu of facts. It is worth while to point out, however, that while most parasites either feed on waste material of little or no value to the host, or else abstract amounts of blood or other body fluids which are negligible in the case of any single parasite individual, there are some parasites which seem to be of definite use to their hosts and there are also others which are definitely harmful, which, for example, actively devour the host tissues and may even kill the host in this way.

And I must also mention the insects which Wheeler calls "social parasites," since they parasitize a colony instead of an individual and contrive to obtain their food and that of their larvae from the supplies brought in by the working members of the colony

As to the secondary characteristics of parasites, the statements that a parasite is usually smaller and weaker than its host and that it often shows what have been called the "stigmata of degeneracy" in the line of structural adaptations for its mode of life, probably need no further comment. As to whether a parasite is normally injurious to its host or not, it is necessary to notice the existence of two sharply conflicting viewpoints.

The biologist, taking a general view of the immense series of parasitic organisms, and noting that only in rare and exceptional cases does obvious injury to the host result from the activities of the true parasites, naturally considers that cases where the parasite does injure the host represent instances of incomplete adaptation. He would point out, for example, that even among the trypanosomes, to pick out a group whose very name brings to our minds a vision of deadly disease, we know many more species which are innocuous to their chosen hosts than we do injurious species. And it is even thought that the species most deadly to human beings are accidental introductions into man and are themselves harmless to their original hosts,

On the other hand, the physician, usually knowing nothing of parasites except the symptoms which some of them produce in human beings, is, of course, prone to believe that the injury of the host is an essential property of a parasite, and to declare that even when we can see no injury one must nevertheless be present.

But now to return from this digression on the definition and main characteristics of a parasite to my original statement, that parasitism could be considered either a wide-spread and fundamental or a rare and recently acquired habit among insects. You will no doubt have noted that all the definitions specify that a parasite lives on or in "another living organism" and derives its food from it. We can not deny that plants are living organisms, and

so at one stroke the great majority of vegetarian insects become parasites. There are, it is true, certain insects which feed on small plants and devour them whole, and may thus be considered as predators on the vegetable kingdom. But the great mass of plant-feeders, including those who eat the leaves, those who suck the sap, the borers, the miners and the gall-makers, must be considered parasitic in their mode of life. In this sense, parasitism might be considered the fundamental mode of life among insects, grading into the saprophytic habit on the one hand and into the predaceous on the other.

But although the plant-feeding habit does come within the definition of parasitism, it is not with that side of the problem that I propose to deal. Ordinarily, when we speak of insects as parasites, we are thinking of those insects which parasitize other *animals*. In this sense, parasitic groups of insects are comparatively rare, and most of them have evidently acquired this habit of life rather recently. Indeed the greatest interest in the study of insect parasitism lies in the study of the intermediate forms which still survive in some cases, to show us how this habit of life came to be adopted.

Among the various groups of insects which are loosely referred to as parasitic we may distinguish three different types, which, following Wheeler, we can conveniently term the true parasites, the parasitoids and the social parasites.

To discuss these three groups in turn, the *true parasites* include those insects which we parasitologists, with our medical affiliations, naturally think of when parasitic insects are mentioned. They conform to our definition in all respects. This group takes in all the lice, both Mallophaga or "bird-lice" and Siphunculata or true blood-sucking lice, all the Siphonaptera or fleas in their adult condition, and a considerable number of distinct groups of the Diptera or flies, such as the ectoparasitic Hippoboscidae or louse-flies, the larvae of the Oestridae or bot-flies, a number of other fly larvae and the whole array of blood-sucking flies, from a tiny sand-fly, Phlebotomus, to the bulky Tabanidae or horse-flies and the vicious tsetse, Glossina. It also includes the few blood-sucking species among the Hemiptera or bugs, such as the bedbugs and the "barbieros" (Triatoma) of the tropics, as well as a few other insects less familiar to us, the tiny bee-louse, Braula, for example, the beaver-beetle and the peculiar little wasp-parasites included in the Strepsiptera.

Since these true parasites are the insects which form the subject-matter of medical entomology and are thus better known to parasitologists than some of the other groups, they may be dismissed with comparatively brief mention. They may be grouped or sub-

divided in various ways. Most commonly, perhaps, we find them classified according to their position in reference to the body of their host. Thus we distinguish external parasites, either occasional, temporary or permanent, and internal parasites, which among the insects are always temporary, that is, always have both a free-living and a parasitic stage in their life-cycle.

Of more importance from the standpoint of disease causation and transmission is a grouping according to the food-habits. The majority are blood-sucking forms, but some fly larvae (Oestrus, etc.) seem to feed on the serous exudates which their presence provokes, others (Gasterophilus, etc.) absorb partially digested food from the stomach, and a few, like the notorious screw-worm (Cochliomyia), actually devour the living tissues. Other fly larvae and most of the bird-lice might be called parasitic saprophytes, since they feed on waste material from their host, either in the intestine or on the body surface.

It is obvious that this parasitic mode of life must have arisen independently in these various groups of insects. And, as we should expect, it has not always arisen from the same foundation. A few examples will illustrate this.

In the Hemiptera or bugs the original food was evidently the sap of plants, and in order to obtain this the bugs have developed a very effective piercing and sucking beak. Some of the Hemiptera, the majority of the family Reduviidae, for example, have discovered that this beak will serve equally well to extract the juices from smaller insects, and have thus become predaceous. And, finally, a few Reduviids, such as the species of the genera Triatoma and Rhodnius, have found that still larger animals, the lower mammals, contain just beneath the skin and within easy reach of the hemipterous beak a nourishing fluid, the blood. Some of these species have even dared to transfer their affections to man himself, when opportunity served, unfortunately carrying with them the trypanosome parasites of their former hosts, which proved so ill adapted to the human body that they produced the disease discovered by Dr. Carlos Chagas, and often known by his name. Here we have the unusual spectacle of a change in feeding habit from plant parasitism, through a predaceous habit to parasitism on lower animals and finally on man, without any essential modification in the organs by means of which food is obtained. The bedbugs probably acquired this habit of life in much the same way as the Triatomas.

Among the flies, the blood-sucking habit has arisen a number of different times and, seemingly, in several different ways. In the mosquitoes it may have arisen directly from a plant-feeding habit.

All male mosquitoes, and in a few genera the females also, feed only on the juices of plants. Even the normally blood-sucking females will feed with avidity in nature on a juicy watermelon rind, and in the laboratory they can be kept alive for months on a diet of water-soaked raisins. Essentially the same condition is to be seen in other groups of flies in which the females alone suck blood, such as the black-flies and horse-flies (families Simuliidae and Tabanidae). In all these groups the habit of feeding on vertebrate blood seems to be a response to the need for a large supply of unusually nutritious food to enable the female to develop large numbers of eggs. But no intermediate forms now remain to tell us just how these females came to discover that blood offered such an accessible and nourishing food supply.

In the blood-sucking midges (Ceratopogoninae) it seems likely that this habit of life evolved through a predaceous stage. While the majority of midges feed on nectar and other plant juices, some of the Ceratopogoninae have developed the habit of frequenting flowers, not to feed on their juices, but to prey on the smaller flies which are attracted to them. Other species of the same group have taken the short step between sucking all the juices of smaller insects and sucking a portion of the blood of larger insects. And finally we have a hint as to how the transition to a diet of vertebrate blood *might* have occurred in the case of a single species of the blood-sucking genus Culicoides. This species, *Culicoides anophelis,* does feed on blood, like most of its relatives, but it obtains its blood-meal by driving its proboscis into the swollen abdomen of an engorged mosquito.

In a small group of Muscoid flies, the blood-feeding habit is common to both sexes. Here we find an exceptionally interesting series of forms, showing not only the acquisition of the blood-sucking habit but also the gradual modification of the fleshy, spongy proboscis of the house-fly into the slender, piercing stiletto of the tsetse. In this group we also find, rather surprisingly, that the blood-feeding habit has become well developed in certain species before any mechanism for piercing the skin and obtaining the blood is available.

The common house-fly, *Musca domestica,* is almost omnivorous. It feeds on any nourishing material which is in liquid form or can be liquefied by the regurgitation of fluid from the fly's crop. While we usually think of a fly as feeding on human foods, on garbage and on liquid filth, it will also take blood or serum when they exude from the body or are otherwise exposed, as any one who has tried to dry blood-smears in a fly-ridden room can testify. Certain other species of Musca have adopted this latter diet exclusively. Lacking

a piercing proboscis themselves, they frequent cattle or horses, awaiting the arrival of a blood-sucking Tabanid or Muscoid fly. As soon as such a fly has pierced the skin it is surrounded by a ring of these Muscas, which crowd and hustle it, sometimes forcing it to withdraw its proboscis and seek a meal elsewhere. When the blood-sucking fly has finished its meal or has been persuaded to depart, the Muscas eagerly surround the site of the puncture, lapping up the surplus blood which trickles from the wound.

Other closely related flies, usually placed in the genus or subgenus Philaematomyia, go a step farther Their probosces are still of the same general form as in Musca, but the base is more heavily chitinized, the spongy labellae are smaller, and the prestomal teeth, which in the house-fly are very minute, are here much larger and form a fairly effective rasp or file, by means of which the fly is able to wear away the epidermis until the capillaries are ruptured and blood flows out to be lapped up by the spongy labellae.

In the more highly specialized blood-sucking genera of this group the proboscis becomes more and more slender, more and more heavily chitinized, and the labellae are ultimately reduced to tiny lobes just large enough to bear the large prestomal teeth Theoretically, this proboscis still works like a rasp, but so tiny are the rasping surfaces and so rapid the action of their muscles, that to the naked eye the proboscis appears to be merely pushed into the epidermis as one might push a pin.

In such permanent ecto-parasites as the lice, the parasitic habit seems to have arisen from a saprophytic mode of life. The best authorities now believe that the bird-lice and the blood-sucking lice are closely related, perhaps representing branches which have arisen from the same common stock and have become specialized in somewhat different directions. Forms which may be close to the original stock from which the lice arose are still in existence under the name of book-lice. The best known of these little creatures is the species which is so often found in old books, or eating up museum specimens or even attacking starched clothing. Others are to be found in the nests of birds and mammals, eating all sorts of débris, including, of course, the cast-off feathers or hair. It is easy to imagine such a species forsaking the nest for the body of the host itself, still feeding on feathers, hair or bits of dead skin. A few minor structural adaptations would then give us a bird-louse. At some time early in the development of bird-lice, some of them must have discovered the great reservoir of nourishing blood just beneath the skin and developed piercing mouthparts for the purpose of tapping it. We can even make a crude approximation of the date of this historic moment in the annals of the lice, for, so

far as we know, those primitive mammals, the marsupials, are infested only by bird-lice, while every other large group of mammals has developed its own characteristic groups of blood-sucking lice. It is possible, then, that these latter originated after the marsupial stage of evolution had been left behind, but before the primitive stock of the higher mammals had undergone any further extensive subdivision.

Many of the parasitic fly larvae seem also to have come from saprophytic ancestors. In the blow-fly group, for example, the majority of the larvae live in decaying meat. Many different species of these flies will occasionally deposit eggs in neglected wounds, both of domestic animals and, more rarely, of human beings. In time of war, when wounded men are often forced to lie out on the battle-field for hours without medical attention, such cases of wounds infested with fly larvae become common Although almost any of the blow-flies may thus have occasional parasitic larvae, there are a few species which have become notorious because of the frequency with which this occurs. In America, for example, the larvae known as screw-worms are frequently found parasitizing both domestic animals and man, sometimes with very serious and even fatal results. Within very recent years, also, a number of blow-flies have developed the habit of laying their eggs on the soiled wool of sheep, and the larvae which hatch from these eggs may attack the skin and other tissues as well as the wool. These "wool-maggots" probably present the gravest problem to-day in Australia, but various American and European blow-flies have also adopted this habit to a considerable extent.

And finally, besides these blow-flies in which parasitism has become more or less habitual, a few species of blow-flies and flesh-flies have recently been found to be obligate parasites in their larval stage. The best example of these is probably *Chrysomyia bezziana,* an Oriental and African species fairly closely related to our screw-worm fly. Colonel Patton has found that an overwhelming majority of the larvae sent in to him from cases of human and animal myiasis in India belonged to this species, and he was unable to rear these larvae to maturity in decaying meat, the original larval food of all the blow-flies. As soon as the meat began to decay, these larvae all died, and it was finally found necessary to transfer the larvae every day to a freshly killed rabbit carcass in order to enable them to reach maturity and pupate.

All the blow-fly larvae are obviously recently developed and poorly adapted parasites, since they always injure their host and sometimes seriously threaten its life. But from a beginning like this, sometime far in the past, there may have developed one section

of the bot-flies, in which we find the larvae living under the skin or in the head sinuses of various mammals, not destroying the host tissues, but merely feeding on the exudations called forth by their irritating presence.

So much for the true parasites among the insects. Now when any entomologist except a medical entomologist refers to parasitic insects, it is extremely likely that he is thinking, not of the true parasites, but of the *Parasitoid* parasites. Most of the truly parasitic insects parasitize vertebrates. The tiny "bee-louse," a degenerate fly which is a true external parasite of drone honey-bees, is one of the few known exceptions to this rule. In nearly every case, then, the insects which parasitize other insects are of the parasitoid group. When an economic entomologist, for example, speaks of the possibility of controlling some insect pest by means of its parasites, he is referring to these parasitoid parasites.

These parasitoid species differ from the true parasites in several ways. In the first place, the parasitoid condition is always one of temporary parasitism. In the insects, a parasitoid species is always parasitic as a larva and free-living as an adult. Further, the parasitism of a host individual by one or more parasitoid larvae almost invariably results in the death of that host individual. The parasitoid condition is, in fact, one of a long-drawn-out predaceous existence. As Wheeler has said, the so-called parasitic Hymenoptera are really very economical predators. The female deposits her eggs or larvae on or within the body of some other insect, larval or adult. The parasitoid larva then starts in to eat up its host *in toto,* but it cannily begins with the fat-body and other tissues not essential to the life and growth of the host. Thus the host may continue for a long time to live and grow apparently normally, and may even reach maturity and pupate, in the case of a larval host. But the end is certain, though delayed. Sooner or later, when the non-essential tissues are all consumed and the appetite of the parasitoid larva whetted thereby, the essential tissues as well are devoured, until nothing remains of the host but an empty skin, which the parasitoid larva often utilizes as a convenient and protected place for its own pupation.

Such parasitoid larvae are particularly characteristic of a number of families of the higher flies and of the great assemblage of parasitic Hymenoptera known as the Ichneumon flies and their relatives. It seems obvious that this habit has been separately developed in the Diptera and in the Hymenoptera, and it is probable that it has been separately developed on a number of different occasions in each of these orders.

Although my acquaintance with these parasitoid groups is very superficial, I will be able to bring out a few of the many interesting features of their characteristics, their adaptations for this mode of life and its possible origins. It is interesting to find, in the first place, that in the majority of cases there is a decided difference in the manner of oviposition in parasitoid Diptera and parasitoid Hymenoptera. In the latter we find a complex, piercing ovipositor, which, of course, becomes the sting in the higher bees and wasps, and is then used for quite another purpose. In the parasitoid Hymenoptera, this ovipositor is generally used to implant the eggs within the body of the larval host. Most of the parasitoid Diptera have no ovipositor or, at best, a "pseudo-ovipositor" like that of the common house-fly, designed for the accurate placing of the egg, but not adapted for piercing. They, therefore, are obliged to lay their eggs or deposit their larvae on the outer surface of the host, leaving the actual penetration to the activity of the larva itself.

These parasitoid insects offer a wonderful field of study to any one interested in complex and often beautifully adaptive life histories, as well as to the workers in economic entomology. While a great deal of information has been accumulated on the taxonomy and the host preferences of these species, very few complete life histories have been worked out, compared with the vast numbers of genera and species included in these parasitoid groups. Almost every serious piece of work on these insects has disclosed some very remarkable examples of adaptive instincts. As every one knows, the Bureau of Entomology has spent a great deal of time and money in introducing parasitoid enemies of the gypsy moth caterpillar into this country. Some of the life histories worked out in connection with this work of parasite introduction are most interesting.

I have already remarked that most of the parasitoid flies lay their eggs or larvae on the outer surface of the host. This habit is not universal, however, and among the gypsy moth parasites some extremely interesting variations from this practice have been found. Any one who has watched a caterpillar feeding on a leaf will recollect how it eats in little semi-circles, biting off small bits in regular order along the whole circumference and then returning to the starting point to begin snipping off another series. Certain of the flies whose larvae parasitize the gypsy moth caterpillar take advantage of this habit by laying their minute, hard-shelled eggs on the moist, freshly cut edges of the leaves, where the caterpillar is likely to bite them off and swallow them on its next round.

Other caterpillars have the habit of leaving behind them as they crawl over a leaf a slender, silken thread, which seems to serve as a blazed trail for their return trip, since they often return later along the same track, guided perhaps by the thread itself, perhaps by some odor emanating from it. Some of the flies whose larvae parasitize these very hairy caterpillars have the habit of depositing their young larvae along these silken trails, the larva being supported in an upright position by a little membranous cup attached to the leaf. This may result in the larva's being able to attach itself to the unguarded ventral surface of the caterpillar when it returns over its previous track.

The work of the gypsy moth laboratory has also revealed some very interesting life histories in the parasitoid Hymenoptera. Many of these latter are what are called "hyper-parasites," that is, their larvae lead a parasitoid existence in another insect larva which is itself a parasitoid. In one such case, the earliest stage of the larva of the Hymenopterous hyper-parasite was found, not in the body of the parasitoid fly larva which is its usual host, but in the caterpillar which serves as host to the fly larva. The young larva of the hyper-parasite searches actively through the whole body of the caterpillar until it finds one of the parasitoid fly larvae, it penetrates into the body of the fly larva and then, surprisingly enough, becomes quiescent and floats passively about in the blood which fills the maggot's body cavity, without feeding or increasing in size. This state of affairs lasts until the fly larva has devoured all the available tissues of the caterpillar, has become mature and has pupated. Then it soon appears that all its eating was of no avail to itself, for the larva of the hyper-parasite, probably stimulated by the beginning of the process of histolysis which accompanies pupation, emerges from the pupa and begins to feed on it externally, by sucking out the pus-like fluid to which most of the tissues of the pupa are reduced at this time. Although the pupa may remain alive for some time, it seems to cease its development as soon as the larva of the hyper-parasite begins to feed. Ultimately the fly pupa, like the caterpillar before it, is reduced to a sac of thin membranes and the full-fed larva of the hyper-parasite pupates within the empty puparium.

Leaving these few cases to serve as examples of the peculiar adaptations of some of the parasitoid life histories, let us ask about the origin of the parasitoid habit of life. Probably it has arisen many different times in several different ways.

Among the parasitoid Diptera, there are a number of families all of whose species have adopted this habit of life, and which therefore give little or no light on the origin of the habit. In the

Sarcophagidae, or flesh-flies, however, are found both free-living and parasitoid larvae. It seems likely that the flesh-flies are derived from the blow-fly group of the Muscidae, therefore we may look on the larvae which feed in decaying meat as the primitive type. Some Sarcophaga larvae feed in fecal matter, perhaps representing a reversion to the ancestral habitat of the primitive Muscoid stock from which the blow-flies may have originated. Others have become truly parasitic in wounds and skin lesions of vertebrates, in the same way that some of the blow-fly larvae have done. Still others have shifted from decaying meat to the dead bodies of insects and other invertebrates, and it is probably from this branch that the parasitoid species of the genus have evolved.

In the parasitoid Hymenoptera, certain habits lead us to suspect that the origin of this habit of life was linked up in some way with a predaceous habit in the adult. The females of many different groups of the parasitoid Hymenoptera feed on the blood which exudes from the punctures made by their ovipositors. Some, whose larvae are parasitic in the hard-shelled puparia of the higher flies, are even known to gnaw a hole in the puparium with their mandibles, feed on the exuding juices, and then run their ovipositors in through the same aperture to deposit their eggs. Such observations show that the instincts of feeding and of oviposition are very closely connected in these insects, and suggest that the habit of ovipositing in other insects arose because of the predaceous feeding habits of the adults.

Other parasitoid forms may well have come from groups which parasitize plants. The Cynipidae, or gall-flies, for example, are a group of Hymenoptera in which the female, as a rule, inserts her ovipositor into plant tissues and deposits her egg there. Either the presence of the egg and later of the larva, or perhaps the presence of some fluid deposited with the egg by the female, so irritates the plant tissues that pathological growths known as galls are produced, within which the larva lives and feeds. As I have already pointed out in the case of the Hemipteran beak, organs which insects have developed for piercing plants are usually adequate for piercing the skins of insects and other animals as well. There is, in fact, a small group of Cynipid Hymenoptera, with the same essential structure as the others, whose larvae live in the characteristic parasitoid manner within the larvae and pupae of our common flies.

Beside the interesting question of the origin of the parasitoid Hymenoptera, this group is of great interest because it is believed that the social Hymenoptera have developed from such parasitoid ancestors. In his recent book, "Social Life among the Insects,"

Dr. Wheeler has developed this thesis at some length, particularly as regards the solitary wasps, which he considers as furnishing the connecting links between the parasitoid and the social forms. Some of the more primitive solitary wasps are really parasitoids, laying their eggs, in some cases, on the bodies of beetle larvae in their underground burrows. Some of these digger-wasps (genus Tiphia) are said to use their sting as a hypodermic needle rather than as a dagger, since the paralysis resulting from the sting lasts only an hour or so, serving merely to anesthetize the grub and render it motionless while the wasp deposits her egg. Other solitary wasps produce a permanent paralysis with their stings, and in some cases the females themselves feed on the paralyzed grubs for several days before laying their eggs on them.

It is rather a delicate question whether the mere act of stinging the victim into paralysis before depositing an egg on it is sufficient to set up any rigid distinction between the parasitoid type of existence and that characteristic of the majority of the solitary wasps. However, most authors do not speak of such a wasp as a parasite, but rather as a skillful huntress, providing for her young.

From searching out the burrows of larvae in wood or earth, stinging them and ovipositing in situ, it is an easy transition to the digging of a burrow of the wasp's own or constructing a cell or series of cells of earth, paper or leaves, and provisioning this "home" with one or a number of paralyzed insects for the larva to feed on. Then we could cite such wasps as Bembix, which leave the burrows open and feed their larvae, day by day, with paralyzed flies. Other similar species prepare the food still further, feeding the larvae with pellets formed from chewed-up caterpillars. Next would come the cooperation of several pairs of wasps in constructing a common nest or comb, and finally the true social wasps, whose colonies each consist of the progeny of a single female, and begin much like those of the higher solitary wasps, but differ in that the majority of the progeny are females which are not completely developed sexually. These under-developed females (workers) remain with the mother and assist her in caring for future broods.

Among the social insects, as among human societies, there occur individuals which contribute nothing to the colony, yet derive their food from it. These Wheeler calls *Social Parasites*. Perhaps we should include in this category as well the so-called parasitic species among the solitary wasps, which construct no cells of their own and do not hunt and paralyze prey, but provide for the future of their progeny by placing their eggs in the cells which have been constructed and stocked with food by some other species of wasp. In some cases the egg or larva which originally inhabited the cell is

bundled out to starve, in others the larva of the parasite devours not only the stored provisions but the original occupant as well.

Cases of true social parasitism, where one species lives in a colony of another species and deludes this colony into both feeding the adult and caring for the progeny of the intruder, are known in hornets, bumblebees and other social Hymenoptera, but the most interesting cases occur in the ants. Since I wish to avoid any discussion of the types of parasitism usually classed under the heads of symbiosis, mutualism, commensalism, and so on, I will make no attempt to deal with the numerous insects of other orders which are tolerated in the nests of ants and termites. I do think it may be valuable, however, to briefly review Wheeler's discussion of the three types of true social parasitism which he recognizes in ants, namely, the slave-makers, the temporary social parasites and the permanent social parasites.

The so-called slave-making ants have long been noted for their habit of raiding other ant colonies, carrying off larvae and pupae, and incorporating the workers which emerge from these larvae and pupae into their own colony. Wheeler has shown that this habit is of very real value in the founding of the colony of the slave-makers. In these ants the young queen seems to be absolutely incapable of rearing her first brood of workers without assistance, so it is essential that she secure workers from some outside source to aid her in starting her colony. The young queen of the "blood-red slave-maker" (*Formica sanguinea*) invades a colony of the larger, black *F. fusca* after her marriage flight, appropriates a pile of pupae, and is adopted by the black workers which emerge from these pupae. The young queen of the "amazon" ants (Polyergus) takes an even more direct method of securing alien workers. She invades a small colony of *F. fusca,* kills its queen in single combat and is adopted by the leaderless colony.

In some species no more raids are made after the colony is well established and the black "slaves" gradually die off, leaving an unmixed, self-supporting colony of red ants. The "amazons," however, have become so specialized for combat that they are unable even to feed themselves, much less care for their young or build nests. They, like the knights of old, occupy themselves only in home defense and foreign aggression, the latter being represented by the raids on black ant colonies, which must be continually carried on in order to keep the "working classes" of the colony up to full strength

In the ants which Wheeler classes as temporary social parasites, as in some of the slave-makers, the parasitism is only evident at the time of founding the colony. In these ants the young queens are

of unusual appearance, either of very small size, peculiarly colored, or furnished with long yellow hairs. After her marriage flight such a young queen enters the nest of some other species of ant, where she seems to completely captivate the alien workers, so that they either allow her to kill their own queen, or themselves eliminate their own "ruler" so that they can devote all their energies to caring for the fascinating stranger and her progeny. This type of social parasite never carries on raids on other colonies, so that when the original alien workers die of old age, a thriving colony of the parasite is left to carry on a self-supporting existence without a trace of its parasitic origin visible.

The most specialized of all the types of social parasitism is that which Wheeler calls permanent or chronic social parasitism. This condition is found not only in several different groups of ants, but also among hornets and bumble-bees, so that it must have arisen several different times among the social Hymenoptera. These permanent social parasites all agree in having no worker caste, but only functional males and females They never occur in colonies of their own, but are always intruders into the colonies of some other species, where they delude the workers into feeding them and according to their progeny the same treatment which they give their own male and queen larvae. Such parasites lead a rather short and precarious existence, since they are unable to care for their own brood and must perish with the death of the host workers.

Among the ants, at least, these parasites begin their career in much the same way that has already been described for the temporary social parasites. The young queen invades the colony of some other species of ant. Here the alien workers at first receive her with suspicion, but soon come to tolerate and finally to adopt her, eventually assassinating their own queen and devoting all their energies to caring for the multitudinous progeny of the interloper. These progeny are, of course, all functional males and females, so that the entire colony must perish when the alien workers die. In some of these permanent social parasites the males are wingless, and the females are fertilized before they leave the nest, instead of during the usual marriage flight.

In all the cases of permanent social parasitism it is noteworthy that the parasites and their hosts are always very closely related species. This seems to be the same type of phenomenon that is found in the so-called "cannibalistic" mosquito larvae, where a few species in widely divergent groups have become specialized for feeding, not on minute animal and plant organisms, but on other mosquito larvae. Here also the "cannibalistic" larvae always feed on the larvae of closely related species which inhabit the same type of

breeding places. Both of these phenomena seem to result from the modification of a single habit without corresponding modifications in others. The species which have developed the predaceous feeding habit, or the socially parasitic mode of life, have not changed their breeding places, or their nesting habits. So, naturally enough, the species with which they come in closest contact and on which they can most easily prey or become parasitic belong to the same ancestral stock as themselves; a stock which retains both in its original and in its modified form the same breeding or nesting habits which it had developed long ages before food scarcity or laziness impelled some members of the stock to prey on or parasitize other members.

Wheeler also points out that the ants which live as social parasites are always rare. This is not surprising. It is axiomatic that any parasite which inflicts serious injury on its host must necessarily be rarer than the host, else the host species, and with it the parasite, would be exterminated. This is true, not only of the social parasites, but also particularly of the parasitoid insect parasites.

This completes my brief and inadequate survey of the various phenomena in insects which may be classed under the general head of parasitism. By way of conclusion, I would like to devote a few lines to the question of degeneration in parasites. Parasites, both among the insects and in other groups of animals, are often spoken of as degenerate organisms. I presume that those who use this adjective mean that the parasites lack or possess only vestiges of certain organs which are found in free-living organisms. This, of course, can not be denied. But no stigma should attach to them on this account. The same process occurs in the evolution of free-living insects. The footless, almost headless, maggot of many of the higher flies, wallowing in the filth on which it feeds, is as degenerate in this sense as any of the parasites.

And, in principle, the mere loss of organs is no criterion of degeneracy. It has even been said that "all progress must necessarily be attended by degeneration," meaning, I suppose, that adaptation to particular environmental conditions must include the loss of some organs as well as the acquisition or development of others. Internal parasites, protected and isolated by the bodies of their hosts, surrounded by food, often obtaining their oxygen directly from the surrounding medium, have naturally lost such useless organs as those which serve for protection, for finding food, and for obtaining oxygen, and are enabled to concentrate practically all their energies on the two essentials of feeding and reproducing their kind. Such specialization does not deserve the name of degeneration, with its retrogressive implications.

On the other hand, it is true of parasites, as of all other animals, that with such complete specialization for one particular environment there comes also the loss of that youthful adaptability which enables a race to survive changes in external conditions, so that it may be said of organisms, as well as of the cells of the body, that specialization is the first step toward extinction. This is true of all organisms, and when we read such a statement as that of Dr. Wheeler that "the number of forms which during geological times have descended to this 'limbus parasitorum' must be considerable," we must also keep in mind the fact that the parasitic forms represent only a fraction of the multitudes of animals and plants which have perished from the earth without leaving descendants because their specialization for particular environmental conditions was so beautifully exact that it left them helpless, with no choice but extinction, when those environmental conditions were replaced by others.

FIVE FUNDAMENTAL CONCEPTS OF PURE MATHEMATICS

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THE five fundamental concepts which we aim to consider briefly are those of natural number, unknown, postulate, function and group. It is not implied that these are the only fundamental concepts of pure mathematics, but they seem to occupy a very prominent position, if not the most prominent position, among the fertile concepts in the development of this subject. The first two appear already explicitly in the work of an Egyptian, commonly called Ahmes, which is supposed to have been written about 1700 B. C., and was recently republished by the Liverpool University Press with an English translation and commentary by T. E. Peet. The third occupies a prominent position in the mathematics of the ancient Greeks, who used it largely for the purpose of divorcing mathematics and philosophy. The last two were not noted explicitly in their general forms until comparatively recent times, having received special names for the first time towards the close of the seventeenth and the eighteenth century, respectively.

It is probable that most mathematicians would place the concept of natural numbers at the head of the fundamental concepts of our subject. This view was expressed by L. Kronecker in the following words: "God made integers, all else is the work of man," while H. Minkowski said in the preface to his "Diophantische Approximationen," 1907, "Integral numbers are the fountainhead of all mathematics." The arithmetization of mathematics during recent decades exhibits more and more clearly that the natural numbers play a fundamental rôle not only in the early development of our subject but also in the recent efforts to secure greater rigor of treatment. By natural number it is customary to denote the positive integers 1, 2, 3, . . . , but B. Russell includes 0 among such numbers on page 3 of his "Introduction to Mathematical Philosophy," 1919. Historically, 0 does not belong to the category of natural numbers. In fact, 1 was not regarded as a number by Euclid and many of his followers even as late as the seventeenth century, but it is now so regarded by all.

While it may be assumed that few mathematicians would object to the statement that the concept of natural numbers is the most fundamental concept of all mathematics, it is not likely that there would be equal unanimity as regards the one which should occupy

the second position. The unknown as it presents itself in an algebraic equation would doubtless receive much support for this distinction. It also appears in the work of Ahmes to which we referred above with a special name meaning *heap*. It stands, therefore, as a fully developed concept at the beginning of mathematical history, and, as we know nothing of the stages of its development, it and the concept of natural number may be regarded as prehistoric mathematical concepts. The great subject known as *algebra* was developed around this concept, and, as algebra is the most extensive algorithm of science, the concept of unknown stands largely for the formal side of this subject In particular, mathematical formalism, which enables us to consider millions of special cases at once, was largely inaugurated through the study of the unknown as it presents itself in an equation.

Among the obvious fruits of this study are the theories of algebraic numbers and substitution groups. In particular, the ordinary complex numbers, whose study occupies such a central position in the mathematical developments of the nineteenth century, received their greatest impulse from the formal solution of the cubic equation during the first half of the sixteenth century. It is important to emphasize the fact that this solution was only formal and was not fully understood until a much later date. Mathematics is not the science of solving problems, nor is it the science of avoiding the solution of problems as has been claimed by some. On the contrary, it aims at intellectual penetration by the most general formalism that can be readily interpreted. This interpretation has sometimes been far behind the development of the formalism, as was the case in the development of the theory of ordinary complex numbers in particular.

The history of the unknown furnishes one of the most interesting examples of capitalization of our ignorance. The mathematician often represents a certain type of ignorance by the symbol x and trails it until it involves itself in the form of an algebraic equation of degree n. He then studies this equation as a subject by itself and finds $n-1$ other unknowns involved therein. His equation thus often gives him much more than he put into it and hence it is quite different from an equation in chemical symbols. In other words, the mathematician has made capital of his ignorance by means of the equation, while the chemist has used the equation as a convenient notation to exhibit clearly what he already knew. It is true that the mathematicians were very slow in taking advantage of some of the fruits of the algebraic equation. In particular, the ancient Greeks ignored this fruit entirely, except that some of the later Greeks used irrational numbers to some extent.

They did not use negative numbers as such, although Diophantus came close to their use by employing certain subtracted numbers as separate entities with which one can operate.

The statement that mathematicians capitalized ignorance in using the algebraic equation may deserve further elucidation, since the evidences tend to show that much of the capital which was later derived from this use in the form of an extension of our number concept was not recognized by the mathematicians for a long time. In fact, it might perhaps be said that it was not sought by them but forced itself on them and enriched them immensely. Ordinary complex numbers, which are now extensively used even in applied mathematics, are needed in the solution of many quadratic equations and present themselves in a very practical form in the common formulas used for the solution of the general quadratic equation in one unknown. The ancient Greeks had rules which are equivalent to some of these formulas They used these rules to find a positive root of many special quadratic equations and hence were on the verge of the wonderful mathematical gold mine represented by the ordinary complex numbers, but they failed to enter this mine. They were not mathematical miners, they were mathematical agriculturists and reaped rich agricultural harvests, as is well known.

For reasons which I fail to understand it is commonly said that the Greeks solved the quadratic equation This statement appears even in some of our best works of reference, such as Pascal's "Repertorium der höheren Mathematik," volume 1 (1910), page 250. In a recent American history of mathematics it is even stated "that the general quadratic equation as we know it to-day was thus fully mastered by the Greek mathematicians." It seems to me that if all that the Greeks knew about the quadratic equation were known by one student, but if this student had no further knowledge about this subject, he would fail to make a passing grade on an ordinary set of examination questions now given to freshman students in our universities. It may, of course, be said that the expression "the Greeks solved the quadratic equation" need not imply more than that they had rules which were equivalent to modern general formulas for this solution, but the quotation noted above shows that even a mathematical historian was recently led to infer much more therefrom and hence its inappropriateness seems to be established.

It was noted above that the ancient Greeks did very little towards the extension of the number concept, although such an extension appears very natural from the stage of advancement which they had attained. On the other hand, they secured immortal glory by the explicit introduction of the third and middle of

the fundamental concepts noted in the opening sentence. The concept of postulate and postulate system is primarily an acknowledgment of ignorance, just as the use of a special symbol for the unknown, but there is also a very marked difference between these two concepts and their effects upon the further development of our subject. The symbol for the unknown used both as an operator and as an operand led to intricacies whose disentanglement gave rise to a very unexpected broadening of the mathematical horizon, while the system of postulates limited the extent of this horizon but led to a much deeper insight into the contents of the field thus limited The concept of the unknown is a concept of extension, while that of a system of postulates is a concept of intension.

The "Elements' of Euclid furnish the best known example of the Greek use of a postulate system. They constitute also one of the best known examples of the divorce of mathematics and philosophy, a divorce which was not always maintained in later years. Even some of the later Greeks, for instance, Nicomachus, tried to effect a reconciliation. It is, however, an interesting scientific fact that a work in which this divorce is so marked became the most noted text-book ever written and is said to have passed through more editions than any other book besides the Bible The so-called Archimedean postulate, which assumes that if there is a difference between two quantities this difference when taken a sufficiently large number of times becomes larger than any given quantity, also enabled the Greeks to make much progress which would have been impossible if they had always admitted the existence of the actually infinitely small quantities. This postulate is implicitly contained in Euclid's "Elements" and was used earlier by Aristotle and possibly by Eudoxus, although the angle between the tangent of a circle and the circle constitutes a magnitude which does not obey it.

From the Archimedean postulate we see that the idea of postulates, introduced by the Greeks, served not only to bring about a practical divorce between mathematics and philosophy but also a restriction of view so as to make advances in this restricted area more effective. The concept of postulate is so widely different from the other four noted in the opening sentence as to make a relative valuation very difficult if not impossible. Those who call mathematics a Greek science would naturally give this concept a relatively high position among the fundamental concepts of our subject. Historically, it is a concept of very great significance since it served to inspire confidence and to secure clarity of view, even if mathematicians for a long period lost sight of the fact that other systems of postulates are possible, and that there is no essential difference between axioms and postulates of mathematics.

The three concepts whose salient features have been outlined above usually receive considerable attention in the courses in elementary mathematics, while the remaining two belong primarily to advanced mathematics. Both of these extend, however, also to the elements of our subject In fact, these particular five concepts have been selected with a view to their very wide range of mathematical influence. The fact that the concept of functions extends into the elements of our subject is illustrated by the appearance of a special name for a trigonometric function in the work of Ahmes We, therefore, find at the beginning of mathematical history a name for what is now known as a transcendental function, but the first definition of the general concept of function seems to be due to John Bernoulli I (1718). There is, therefore, a period of more than three thousand years between the time when a name for a special function was first used and when a general definition of the concept of function was first made known.

It seems reasonable to regard the general concept of function as an outgrowth of the concept of unknown. It was noted above that the unknown frequently presents itself entangled in the form of an algebraic equation. Other expressions involving the unknown appeared early in the development of our subject. It was natural to consider these expressions as symbols by themselves and to allow the unknown, or unknowns, involved therein to assume various values The corresponding values assumed by or assigned to these expressions when the unknowns are regarded as variables are also variables and are *functions* thereof. Since related variables present themselves so commonly in nature it is evident that a training in functional thinking is of great usefulness to those who seek an intellectual penetration into their surroundings. This explains the growing emphasis on the concept of functions in some of our elementary courses of mathematics as well as the appearance of so many works devoted explicitly to the subject of function theory.

Since the last one of the five fundamental concepts under consideration is probably the least generally known and some readers may be inclined to think that it should not be included among the five most fundamental concepts of pure mathematics it may be noted here that in the introduction to his book entitled "Einleitung in die Theorie der Invarianten linearer Transformationen auf Grund der Vektorenrechnung," 1923, E. Study remarks that mathematics concerns itself with a system of laws which are mostly of a group theoretic kind. It may also be noted that in one of his last addresses H. Poincaré said that "the theory of groups is, so to say, entire mathematics divested of its matter and reduced to a pure form" ("Acta Mathematica," Volume 38 (1921), page 145). The

American reader may be interested in the fact that a recent French writer said "the theory of finite groups has become a theory which is largely American" (A. Buhl, "L'Enseignement Mathématique," Volume 22 (1922), page 216).

One of the most important mathematical groups is composed of the positive rational numbers as regards the operation of multiplication. This group appears in the work of Ahmes with the special name of number, and it constituted the totality of the number system for about two thousand years thereafter when, as noted above, some of the Greeks during the period of decadence calculated with irrational square roots as if these roots were numbers, without considering their geometric origin. It is not likely that the ancient Egyptian mathematicians had a clear notion of this number group or of the trigonometric function to which they gave a special name. The founding of the theory of groups as well as the founding of the theory of functions lay more than three thousand years ahead of their times. The fundamental nature of the concepts of group and function is, however, partly exhibited by the fact that special cases of these concepts presented themselves so early and continued to present themselves in the later developments.

Even those who would not agree that the five concepts which are under consideration constitute the best selection possible as regards fruitfulness in the development of pure mathematics would doubtless agree that they do constitute a very significant set of concepts whose dominating influence entitles them to the respect which we render to the mighty forces of this world. In view of their great simplicity one might at first not suspect that they are the source of so much that appears complicated and profound. They have not only led to new domains of thought, but they have also tended to exhibit order where there seemed to be chaos, and comparative simplicity where otherwise there seemed to be only an endless multitude of special cases. The formalism to which they have given rise constitutes an intellectual elegance which is not superficial and fruitless but penetrating and enriching, since it gives us an insight into how nature works without losing ourselves in a maze of apparently disconnected facts. Fortunately, it always leads to new difficulties and the exposure of these has ever been the source of scientific progress.

IS THERE A NATURAL LAW OF INEQUALITY?

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THE doctrine of equality is derived chiefly from Rousseau, Locke, Montesquieu and other social and political philosophers of the latter part of the eighteenth century, although it was implied long before in the Roman juridical maxim, "omnes homines natura aequales sunt" It was formally asserted in the French Declaration of the Rights of Man, in 1789, and had previously been expressed on this side of the Atlantic in the Virginia Declaration of Rights, June 15, 1756, and in the Declaration of Independence in the famous proposition, "All men are created equal."

From the foundation of this government until recently, except in the south for a short period before the Civil War, this doctrine has been almost generally proclaimed as the fundamental idea and logical basis of democracy. The southern states attempted to found a government upon the opposite principle. After the organization of the Confederate States of America, and on his election to the vice-presidency thereof, Alexander H. Stephens, in an address to the citizens of Atlanta, said that the foundations of the new government were laid "upon the great truth that the negro is not equal to the white man, that slavery, subordination to the superior race, is his natural and normal condition" "This, our new government," he continued, "is the first in the history of the world based upon this great physical, philosophical and moral truth." The outcome of the war, however, discredited this "great truth," and many doubtless supposed that we should hear no more of it. But within the last few years, and particularly since the Great War, far from being admitted as a self-evident truth, the proposition that all men are created equal has been vehemently denied, and the old doctrine of inequality has again been brought forward with claims of a natural sanction and an ethnological and scientific foundation.

A recent critic (Joseph Collins), for instance, writing of Georges Duhamel, the French poet and pacifist who worked in French hospitals during the late war, says:

> He saw man in his agony give the lie to the most misleading of all statements: that man is born equal. For neither in living nor in dying is there equality. Men are equal, we trust, before God, and they are alleged to be equal before the law, but after that, equality of man does not exist.

After this deliverance we are not greatly surprised to find the same critic giving utterance to this further contribution to political philosophy: "If any *ex cathedra* statement is justifiable it would seem to be this—the World War flowed more or less directly from the revolutionary movement which began with the dissemination of the doctrine of the French philosophers, especially Rousseau, toward the end of the eighteenth century" Rousseau, then, with his specious doctrine of equality, not Bismarck, the Hohenzollerns and Prussian (and other) militarists, was responsible for the late war. It would be gratifying to have a question thus settled about which there has been much difference of opinion—if only it could be settled *ex cathedra*.

Again, from an article by President George B. Cutten, of Colgate University, published in the New York *Times,* July 1, 1923, and entitled, "Nature's inexorable law—inequality," we learn once more that the statement in the Declaration of Independence that "all men are created equal" is "untrue to facts." "The phrase sounds well," he says, "but when we attempt to find anything in nature which accords with it we are doomed to disappointment, for nature's inexorable law is inequality."

This article, by the way, is apparently only an echo of the doctrince proclaimed by Lothrop Stoddard in his book, "The Revolt against Civilization." The second chapter of that book is entitled "The iron law of inequality." It begins as follows:

> The idea of natural equality is one of the most pernicious delusions that has ever afflicted mankind. It is a figment of the imagination. Nature knows no equality. The most cursory examination of natural phenomena reveals the presence of a Law of Inequality as universal and inflexible as the Law of Gravitation.

Thus we learn that, owing to a law of inequality in nature, the famous statement of our Declaration of Independence that "all men are created equal" is palpably absurd.

Well, if it is it is not because of any natural law of inequality, for there is no such law, as we shall now see.

On what ground is it asserted that there is a natural and iron law of inequality? It is merely the ground of the indisputable fact of infinite variety in nature. No two things in nature are exactly alike. This holds, of course, with regard to men. No one is likely to dispute the declaration that of the billion and a half or more people in the world it would be impossible to find any two of them that are in all respects exactly alike. Not even "identical twins" are identical. When nature makes a man she breaks the molds. Now, is this admitted fact, or so-called law, of variation equivalent

to a law of inequality? Not unless variation and inequality are equivalent terms, which plainly they are not. "No two individuals are ever precisely alike," says Stoddard "The leaves of the trees, the blades of grass, the flowers of the field, no two of these are either alike or equal," echoes President Cutten. But why "alike or equal"? Are these terms interchangeable? Certainly not. Things are alike or unlike as an objective fact of nature. They are equal or unequal only as judged by man from a subjective standard of comparison. Man, then, not nature, determines equality or inequality. His standards vary; so also will his judgments as to the things compared. The same things, though visibly unlike, may be adjudged equal at one time, unequal at another. A shift of standards may reverse his judgment A pansy and a peony differ in size, shape, color and fragrance; but whether they are equal or not, say for decorative purposes, depends upon the design and taste of the decorator. A percheron and a Kentucky thoroughbred are obviously unlike; but to say that they are equal or unequal is meaningless unless the standard or viewpoint of comparison is known. One is superior for draft purposes, the other for racing. They may indeed be equal from the standpoint of height or beauty or value. Is it not clear, then, that while variation or unlikeness is undoubtedly found in nature, inequality or equality exists there only as man interprets the unlikeness, that is, only in the mind of man as the expression of a judgment that may be true or false? The law of variation, then, is not a law of inequality.

Lest it be said that we are stating a distinction without a real and significant difference, let us pursue the subject a step further. A natural law admits no exception. An exception proves a rule, but it destroys a law. Are there, then, no exceptions to the so-called natural law of inequality? Is it true that no two things in nature—leaves, blades of grass, flowers, men—are equal in any respect? Obviously, leaves may be naturally equal in length, grass in color, flowers in beauty and men in size or weight. Such obvious exceptions to natural inequality are sufficient to dispose of this so-called "iron law," and to show that conclusions based upon it or inferences drawn from it are invalid. "There is in fact," says Stoddard, "no such word as equality in nature's lexicon." It is equally true that no such word as inequality is to be found there.

What the opponents of the doctrine of equality have mistaken, then, for a natural law of inequality is merely the fact of infinite variety in nature, plainly recognized by students of nature for more than a hundred years. It is a beneficent fact, too, for without it there could have been no evolution through natural selection; there would have been nothing from which to select. But it is rather a

fact than a law, and the fact of variation, as we have seen, has nothing to do with equality or inequality unless or until man appears with some standard of comparison, and this standard with respect to men may not have anything particular to do with social policy or social progress. There is, therefore, we repeat, no such thing as a natural law of inequality.

But, in passing, suppose there were such a law, what of it? Is a natural law an insuperable barrier to progress? Quite the contrary, it is a condition to progress. If there were no natural law of gravitation, how could we build securely? If there were no natural laws of heredity, how could we hope to develop a science and an art of eugenics? Suppose, then, that men were made unequal in certain respects, it does not follow that they must or should always remain so. Certainly social progress must be in the direction of the removal of artificial inequalities. Why not also of certain natural differences? This, however, is a digression.

Artificial inequalities, it will be asserted, are the results of natural individual differences, particularly differences in mental capacity. Here we reach the crux of the matter under discussion. What the advocates of the doctrine of inequality are chiefly concerned with are inequalities in native intelligence. They wish to show, not merely the undisputed fact that such differences exist, but that they are merely manifestations of the divine order of things, natural and ineradicable, and that we should proceed accordingly in government and in education. Here again their logic is at fault. No two things in nature are alike, they say, therefore no two men are equal in intelligence. But it is not true that no two men are equal in intelligence or mental capacity. If our standardized tests of intelligence be applied to a large number of men, it will be found that some of them, indeed many of them, will have the same intelligence quotient. This means, at least, that they are so nearly equal in intelligence that the difference can not be determined by any tests thus far devised.

If, in order to escape the inevitable negative conclusion implied by this illustration with respect to the existence of a natural law of inequality, it be declared that what is meant is that men in masses, that is, in classes and races, are unequal in intelligence, then we have a question of fact, not a corollary of a law of nature, that can be determined only upon the basis of the pertinent scientific evidence. Now, what evidence have we to support the doctrine of inequality even of races? The careful student must admit that it is very little.

The best witnesses on this point are the ethnologists and anthropologists. Let us note what some of them have to say in regard to it.

Professor Franz Boas, certainly one of the foremost anthropologists of this country, declares that the belief in racial inequality is

> based essentially on the assumption that higher achievement is necessarily associated with higher mental faculty, and that therefore the features of those races that in our judgment have accomplished most are characteristic of mental superiority. We subjected these assumptions to a critical study, and discovered little evidence to support them. So many other causes were found to influence the progress of civilization, accelerating or retarding it, and similar processes were active in so many different races, that, on the whole, hereditary traits, more particularly hereditary higher gifts, were at best a possible, but not a necessary, element determining the degree of advancement of a race.[1]

In his opinion we are not able at the present time to form a just valuation of the hereditary mental powers of different races.[2] This is practically the opinion of the other leading authorities in this field. "No proof has been forthcoming of the inferiority of the other racial stocks to the white," says Goldenweiser[3] "Any successful attempt to evaluate the innate mental differences of peoples," says Holmes,[4] "would involve a thorough investigation by the best modern methods and on an extensive scale. As no such investigation has ever been made we have no very adequate basis for asserting which of the civilized peoples of the earth are the most highly gifted with inherited qualities." Wissler, though he believes there are indirect evidences of racial inequality, declares that "the import of our comparative studies of culture history is that no one racial strain, like the Nordics, for example, can lay claim to more than an incidental contribution to culture as a whole."[5]

Finally, Kroeber, after a critical examination of conclusions drawn from the army tests, thus expresses his view:

> As a matter of fact, the bodily differences between races would appear to render it in the highest degree likely that corresponding congenital mental differences do exist. These differences might not be profound, compared with the sum total of common human faculties, much as the physical variations of mankind fall within the limits of a single species. Yet they would preclude identity. As for the vexed question of superiority, lack of identity would involve at least some degree of greater power in certain respects in some races. These preeminences might be rather evenly distributed, so that no one race would notably excel the others in the sum total or average of its capacities; or they might show a tendency to cluster on one rather than on another race. In either event, however, the fact of race difference, qualitative if not quantitative, would remain.

[1] "The Mind of Primitive Man," New York, 1921, p. 244.
[2] *Op. cit.*, p. 122.
[3] "Early Civilization," New York, 1921, p. 6.
[4] "Studies in Evolution and Eugenics," New York, 1923, p. 92.
[5] "Man and Culture," New York, 1923.

But it is one thing to admit this theoretical probability and then stop through ignorance of what the differences are, and another to construe the admission as justification of mental attitudes which may be well founded emotionally but are in considerable measure unfounded objectively.

In short, it is a difficult task to establish any race as either superior or inferior to another, but relatively easy to prove that we entertain a strong prejudice in favor of our own racial superiority.[6]

We quote these ethnologists merely to show the status of the question of racial equality or inequality. We do not advocate the one or the other. We are merely concerned with showing that inequality in races, classes or individuals is not to be inferred from an iron law of nature, but is only to be determined upon the basis of scientific evidence, and that evidence is as yet somewhat meager.

We have shown that there is no iron law of inequality in nature. But in so doing we have shown also that neither is there a natural law of equality. Nature knows no more of the one than of the other. Must we not admit, then, that the declaration that "all men are created equal" is an altogether unfounded assertion, a mere glittering generality or worse?

Before we dismiss the proposition as the "most misleading of all statements" let us see whether after all it does not embody something like a self-evident truth. It would appear to be self-evident that all men are created equal in helplessness, in ignorance and in innocence. Perhaps there is some other respect in which the natural equality of men was thought to be self-evident by the fathers of this republic. What did they really mean by the proposition? What was their subjective standard of comparison?

Well, they could not possibly have meant what the advocates of inequality imply they did. Variety in nature—natural differences in plants, animals and men—is a fact so obvious that it could hardly escape the observation of a child. Certainly it was not overlooked by the philosophers of the eighteenth century. Rousseau himself recognized the existence of what he called natural or physical inequalities, such as "differences of age, health, bodily strength and intellectual or spiritual qualities," and carefully distinguished them from "the different privileges which some enjoy, to the prejudice of others, as being richer, more honored, more powerful than they, or by making themselves obeyed by others." Such inequalities, he thought, are dependent upon "a sort of convention and are established, or at least authorized, by the consent of mankind." It was only the latter that he wished to remove. Surely nobody in his senses ever meant to say that men are equal in all respects, that is, equal by every standard of comparison. We pay little homage to

[6] "Anthropology," New York, 1924, p. 84–5.

the intelligence of the framers of the Declaration of Independence, then, and give little evidence of our own by asserting or implying that they ignored or meant to deny the fact of variation. They were as clearly aware as President Cutten, that, from the corresponding standards, "men are unequal physically, unequal mentally, unequal socially," though they would not have assigned the entire responsibility for that fact to a law of nature. Some of these inequalities are plainly due to inequitable and unjust social conditions. What, then, did they mean?

"Most people think," says President Cutten, "that the proud, slave-holding, Indian-hating aristocrats who were responsible for the Declaration of Independence meant that all human beings were equal. Of course, they didn't. They meant that certain property holders on this side of the Atlantic were equal to certain property holders on the other side—that was all Negroes and Indians and poor whites and women were not equal to Virginia planters and political leaders—not by a jugful." This, however, is a libel on the men who framed the Declaration of Independence. They knew and admitted that slavery was an evil. But it was in existence, it was entrenched behind constitutional guaranties, they had no hope of its immediate elimination. They were confronted by a condition, not a theory. They regarded slavery as wrong, and looked hopefully to its gradual and final extinction. This was proved to the hilt by Abraham Lincoln in his Cooper Union speech, February 27, 1860. When they said, then, that "all men are created equal," they meant exactly what they said. They meant that from a certain viewpoint, the viewpoint they had in mind, men should be regarded as equal. To assert the contrary is to belittle them to the stature of cheap politicians formulating a party platform merely to catch votes. But what was that viewpoint?

The founders of this republic were not interested in biological and psychological comparisons. They were concerned with a form of government and a doctrine of rights. The Virginia Declaration and the French Declaration were both declarations of rights. The French Declaration reads, "All men are born free and equal; not one of them has more right than another to make use of his natural or acquired faculties; this right, common to all," etc. The Virginia Declaration declares, "All men are by nature equally free, and have inherent rights," etc. So the framers of the Declaration of Independence, equally concerned with human rights, meant to assert that all men, from the viewpoint of just human relationships, are equal in their rights to participate in their own government and to enjoy life, liberty and the pursuit of happiness; that these rights are inalienable; that one man, as much as another, is entitled to develop

his personality without the selfish interference of those who would use him as a means to their own ends. They meant to assert that self-government is the only rightful basis of any government. Lincoln suggested one aspect of the idea when, in speaking of a black slave woman, he said, "In some respects, she certainly is not my equal; but in her natural right to eat the bread she earns with her own hands, without asking leave of any one else, she is my equal and the equal of all others." This is what the Declaration of Independence asserts, and this is what the philosophers of the eighteenth century had in mind. They were merely stating the fundamental principle of democracy as against the selfish, brutal and soul-destroying rule of a hereditary dominant class. And this principle is a vital truth and must be maintained against Nordic propaganda and against pseudo-scientific declarations concerning natural racial or class inequality. All honor, then, to Jefferson, as Lincoln remarked, all honor "to a man who, in the concrete presence of a struggle for national independence by a single people, had the coolness, forecast and capacity to introduce into a merely revolutionary document an abstract truth, applicable to all men and all times, and so to embalm it there that to-day and in all coming days it shall be a rebuke and a stumbling block to the harbingers of reappearing tyranny and oppression."

Why, then, this modern and apparently concerted effort to make the Declaration of Independence appear ridiculous by insisting upon a literal and general interpretation of the phrase, "all men are created equal," and by attempting to prove the fathers of our republic ignorant or insincere because they approved the sentiment?

When we find it proclaimed that the doctrine of equality is absurd because men are so obviously different, that by a great and recent discovery in biology it is revealed that no two plants or animals, much less men, are exactly identical, that there is an iron law of inequality, and that our Declaration is an outworn and delusive document, we suspect that there is behind it some other motive than the disinterested desire to set the world right on a question of natural history. There is, we believe, an ulterior motive, and that motive is to discredit democracy. The denial of the doctrine of equality may be taken as an infallible sign of political reaction.

President Cutten, for instance, makes his discussion of nature's so-called inexorable law of inequality the prelude of an attempt to prove, first, "that socialism is psychologically impossible," mental inequality being the chief barrier and the greatest argument against it, and that "the present organization of labor unions is impossible

as a permanent scheme." Secondly, and more important, that democracy, as we are accustomed to conceive it, is also impossible. "Our nation," he says, "is ruled by a few men now just as it always will be. Only a small proportion of people in our country, or any country," he says, "have sufficient mental ability to govern themselves." They must, therefore, be governed by others. He would improve upon Lincoln's famous Gettysburg speech by defining democracy as a "government of the people, for the people, by all those of the people mentally able and morally capable of doing so"—that is by *us*. He apparently fails to see that this is oligarchy, an aristocracy, not democracy He accepts, too, the fallacious statement of Babson that "statistics teach us that practically all we have to-day in the form of factories, stores, railroads, steamships, newspapers and books is due to the enterprise of only two per cent. of the population," and thinks the fact that the major part of the nation's wealth is owned by less than two per cent. of the population is about as it should be, since this two per cent. constitutes almost half of the mentally superior people.

Stoddard, also, posits his "iron law of inequality" in order to establish a new political philosophy, what he calls Neo-Aristocracy. This is that the great mass of the people, fully 70 per cent, he says, are incapable of self-government and must be governed by their superiors "Nature has decreed them uncivilizable." They perceive somehow, however, and in spite of their mental incompetence that progress is not for them, that they are getting the worst of it. "Let us, then, understand once for all," he says, "that we have among us a rebel army—the vast host of unadaptable, the incapable, the envious, the discontented, filled with instinctive hatred of civilization and progress, and ready on the instant to rise in revolt"—in revolt against civilization, mind you, and not against the ineptitudes, injustices and iniquities of civilization. "Here are foes," he says, "that need watching. Let us watch them." According to the figures of the army tests, which he accepts uncritically, 70 per cent. of our enlisted men in the Great War are among these foes. They belonged to that great army of "the unadaptable, the incapable and envious." Still they fought, or were ready to fight, the great war for democracy, and fifty thousand of them gave their lives to that great cause. Who provoked that war or so grossly mismanaged the affairs of government as to make it inevitable? Who led the world into the conditions that made it a slaughter house, resulting in the destruction of ten millions of men and three hundred and fifty billions of property? Certainly not this class, but their so-called "mental superiors."

If anybody needs watching, then, is it not rather those who would recover the remnants of the doctrine of inequality from the battlefields of Europe and of America where we had thought it was shattered forever so far as this country is concerned, and piece it together, refurbish it and parade it as a sacred political doctrine sanctioned by an iron law of nature; is it not rather those who because of the way it happens to have been expressed a hundred and fifty years ago pour ridicule upon the doctrine of equality and deny the equal and inalienable right of men to life, liberty and the pursuit of happiness. "As if it harm'd me," as Walt Whitman said, "giving others the same chances and rights as myself—as if it were not indispensable to my own rights that others possess the

PHILOSOPHY IN MEDICINE

By Professor HORST OERTEL

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It is a common and prevalent opinion of the present day that philosophy—that is, the general knowledge and ideas of the nature and relation of things—and medicine have nothing to do with each other. Any attempt to include the study of philosophy as a preliminary requirement for the study of medicine would create laughter, a storm of protests, and, if it came to a vote at all, be summarily rejected with ridicule by many of our modern medical faculties. Long speeches would be made around faculty tables that we are to educate practitioners, not scientists, that the requirements of preliminary training, even in the fundamental sciences, should be reduced to the absolutely necessary minimum, and that we must remain "practical." Few of those arguing in this manner would appreciate that they themselves are already preaching a system of philosophy—naive, crude and superficial though it is—which, nevertheless, embodies a general conception and belief of life and order of things

And thus it is; we may all ridicule philosophy, smile at the involved thoughts and unpractical ideas of the "school" philosopher which we reject, because we do not understand them, or because their contents do not come within our own field of vision, but, after all, we are all moved by the same questions: What is life? What is our position and mission in it? Whence come we? Where are we going? What are our relations to other beings, and to the things around us? In short, what is the secret of this world? These ideas come to us at one time or another, whether we wish to entertain them or not. And in spite of our efforts to sidestep them or to abandon them as useless, they force us with elemental strength to some sort of answer. Thus it happens that every human being, savage, business man, even lawyer and doctor, adopts a position in regard to these questions. Our whole existence is shaped by this position. Inevitably the human mind is driven to it. The philosophical attitude of the individual may not be original with him; frequently it is not; but nevertheless it exists in him and controls his views and actions. One may venture to say that the force of philosophical conceptions is so strong that they, more than any other, determine man's actions and thus the history of the world. This is equally true of the grossest materialistic and selfish ideas as

of the highest spiritual altruistic motives of which the human mind has ever been capable. Thus, Hegel, properly and profoundly, defined the history of philosophy as "the history of the world-moving ideas."

Thus also the sciences are children of philosophy or of that impulse which, for one or the other reason, forces the human mind to investigate the nature and connection of things True enough, the immediate impetus of progress was often a very practical or protective one, but the result became at once the basis for generalization, and when the desired result was defeated, it became the source of speculation. When the king of Siam was told at one time by the Dutch ambassador that in his country, Holland, water would solidify at certain times of the year so that it was possible to walk on it, the oriental monarch refused to believe it on the ground that the very idea of water necessitated a fluid quality—a perfect example of philosophical empiricism.

Out of such at first naive and unconnected conceptions grew, with experience, scientific thought and method of reasoning. Conflict with dogma and authority stimulated their advance to greater clarity of fundamental principles and correctness and simplicity in putting questions. Thus arose our present scientific method of investigation. This evolution was a long, laborious, often dangerous one. It proceeded unevenly in the different branches of science, through innumerable personal sacrifices, and it is still far behind in many. The biological sciences, upon which the practice of medicine is based, arrived latest at this method, and are, therefore, still least developed in this respect. Of these again, pathology, the science of disease and the immediate support of medicine, still wears a child's habit as a science. Strange as it may seem, it is still clothed in the garb of the oldest scholastic period of philosophical reasoning. For it has not yet learned to distinguish fully between what is scientifically established and what is assumed. That is the greatest fault of the medicine of to-day. Here I enter upon a plea for the necessity of a philosophical sharpened mind, in order to intelligently follow, appreciate and command the contents of modern medicine. Let me explain!

All human reasoning has two paths of approach: Rationalism and empiricism. The first endeavors to construct things and occurrences out of the mind alone, the second out of experience. The first goes back in modern philosophy to Descartes, the second to John Locke and David Hume. These were combined by Kant into a conception of nature as nothing else but "a system of phenomena which is ordered by the lawful function of our intelligence," and which, not through intellect but "will," leads to higher understand-

ing and moral concepts of the world.* In other words, observations and experience through wilful thought furnish us scientific knowledge and interpretation of the world. Out of these two mental functions arises understanding by causal connection of natural phenomena. This is at first of course quite incomplete and therefore full of exceptions. It is perhaps best typified by popular medicine, which abounds with exceptions which the ordinary person disregards.[1] Thus, if you expose yourself to a draft, you catch cold, but not in every instance. If you have a cold you have fever, but not always. If you take a certain drug, this or that effect will follow, but not always, and sometimes something quite different. In a large number of individuals, any desire to establish a further causal connection never arises. They are satisfied with the old "no rule without exception," or "the exception proves the rule."

Originally, even the deeper philosophical insight, as exemplified by Aristotle, recognized exceptions in natural occurrences, which had to be explained through uncontrollable properties of matter or through a natural lawlessness of action. But gradually causal connection was given a stricter form and requirement. At present it is the duty of all sciences to establish causal relations which proceed with mathematical precision according to never-changing rules of cause and sequence. No physical consequence, therefore, without physical antecedence.

So far, only physics has carried this principle to strict general application, and the laws of mechanics may be regarded as the typical example of natural lawfulness. Descartes insisted upon this for the external world, Hobbes and Spinoza insisted upon it, long ago, as a necessity also for the internal, psychic world. How near are we to it in the biological sciences, more particularly in the field of disease?

We must first make clear to ourselves the meaning of causal connection! The popular belief is that anything, which is immediately followed by a phenomenon in a large number of instances, is its cause. That, however, is entirely unsatisfactory, or, at least, insufficient to establish cause. For the relations of the sequence to the accidence may also be casual, indirect and circumstantial. For this reason, Roux, the founder of evolutionary mechanics, insists that every causal knowledge of a phenomenon must include the complete connected chain of all events which are responsible for it, and, I

* Nothing greater has ever been said in this connection than Kant's phrase: "The starry heavens above me, the Moral Law within me." (Kritik der praktischen Vernunft.)

[1] I take this example from Paulsen's well-known "Introduction to Philosophy."

should add, *in their proper position,* not only one or several, remote or immediate, links. When, for example, we speak of bacteria as *causes* of disease, we are, strictly speaking, not correct. For, while bacteria may be etiologically concerned, they do not give us any understanding of the part they play in infection or of the mechanical connection and nature of the subsequent disease. Thus, the finding of microorganisms gives us no information about the anatomical selection, the mode or origin, the manner of development and of the specific expressions of the anatomical changes which furnish the objective basis of diseases. Consequently, there have been introduced by obliging bacteriologists and pathologists, in order to rapidly hitch their sciences to clinical medicine, all sorts of indefinite, largely hypothetical conceptions, such as "virulence," "attenuated forms," "variability," "resistance," "strains" (which are distinguished by equally uncertain reactions), "individual susceptibility," "carriers." All these cover up deficient knowledge of causal relations, are, at the best, heuristic. The calamity, however, is that these words are construed by some as scientifically established connections of circumstances which may be regarded as finished entities, and thus may be drawn upon to *explain* natural phenomena (to this I shall refer later).

A surgeon told me once that bacteriology was unsatisfactory and worthless to him, because no matter whether he sent a specimen of pus from any part of the body and from quite different diseases or a swab from any ulcer or from a phlegmon or from the throat, or, finally, blood for culture, the report would be nine times out of ten a kind of streptococcus or contamination. He was quite right, in a sense, but he lacked that penetration which should have told him that bacteria are not *the* causes of diseases, but only one of the factors which must be considered in the construction of the causes, and I quite agree that the ordinary routine of bacteriological examination as applied in clinical medicine is a statistical entertainment which gives us not the slightest information as to their rôle in the origin and subsequent development of the disease. Such men are quite at a loss to understand the finding of even pathogenic bacteria in healthy subjects. But even accepting bacteria as a factor which enters into the cause, we possess no exact knowledge of how and how far they enter. We are consequently perfectly unable to define *their exact position* in the causative, nosological complex, simply because we have not the slightest knowledge of the mechanism of the relation between bacteria and body cells. The introduction of such hypothetical conceptions as toxin, endotoxin, esotoxin, do not get us much further, because their existence, molecular constitution and interrelation with the organ-

ism's cells are unknown, and only based on an unfortunately only too variable symptomatic experience. In every instance, causal connection, and that is really the crux of the whole matter, *must establish the connecting bridge between cause and sequence.* In pathology, we possess only one great, although necessarily incomplete, attempt in this direction, that is, the cellular pathology of Virchow, for Virchow substituted for hazy ideas of life and its disturbances mechanical cell acts in response to definite stimuli. This is perhaps best illustrated by his ideas of inflammation. Before him existed only very indefinite views on the nature of inflammation, based either on subjective symptoms or on symptomatic vascular changes or on certain products of inflammation (exudate) or, finally, on injury to nerves. Virchow wiped all these away, for he saw clearly that any explanation or definition must give an account of the mechanism of the lesion. Thus, he boldly placed inflammatory action into the cells, and in his famous article on "Parenchymatous inflammation," traced, as well as he could at the time, the whole causal connection of the lesion, from the stimulus to its end changes, in the cells of the parenchyma. It was a grand attempt at a mechanical explanation. His work, therefore, although superseded in many respects by the discovery of new facts, nevertheless remains as the first monumental effort in pathology to push the mechanical causal connection of pathological phenomena as far as it will go. Thus Virchow broke with that sort of pathological investigation which is willing to rest its mind, as Kant puts it, "upon the bolster of unknown dark qualities." Throughout the whole domain of pathology, Virchow endeavored to introduce mechanistic explanations and, more than any one before or after him, he was instrumental in relegating vital forces and other transcendent powers in the explanation of normal or abnormal processes of life to the background.

It was natural, however, that Virchow, at his time, could not entirely succeed in this task, and he himself was obliged to retain certain *a priori* or transcendental conceptions, where the pure mechanistic explanation failed. Thus, the cell as a "vital unit" endowed with "vital activity" is "passive" in irritation, "active" in reaction, "adapts" itself to "injury" or "resists" it. It has attributes of "repair," "recovery" and "healing" and performs "selective acts." Such and similar transcendental[2] ideas persisted through the reformation of cellular pathology. Thus also Virchow was unable to overcome the idea of transcendent[2] purposes, or the

[2] I use the term *transcendental* in this connection in the Kantian sense as applying to *a priori*, categorical ideas which are necessary to experience, as compared to *transcendent* which applies to what is beyond experience. Identification of these has led to much confusion in pathology.

teleological explanation of natural phenomena which is so often intimately associated with and confused with these *a priori* or transcendental ideas. With the continuation of these ideas, not in sense of convenient categories or as *names* for as yet unexplored or not understood natural phenomena or even as heuristic principles, but as real powers which were coupled with teleological qualifications, the whole of scientific pathology broke right in the middle. Take all the bacteriological, and especially immunological, so-called explanations. What are they? Expression of causal relations or causal explanations? Not at all! Entirely metaphysical ideas! The definitions of "immunity" itself, "resistance," "defense," "purpose," "effort," "agglutinins," "precipitans," 'lysins," "antibodies," "complement," "opsonins," and so on, permeate in the shape of real entities, like a pre-Virchowian nightmare, the whole scientific texture of the infectious diseases. Now it might be urged, once more, that these are simply names or heuristic principles which are employed to cover defects, and as that, they would demand a certain temporary standing. But actually that is not the case, for they are used to *explain* other unknown natural phenomena. Thus, for example, "inflammation" and "immunity" are given a "purpose" of "defense action." Can any one think of anything less scientific and more confused and muddling in reasoning? For what does it mean? If it means anything at all, inflammation and immunity are elevated to the position of independent entities which perform something which is entrusted to them by an unknown power outside of them, in order to protect, defend or heal the individual. Thus, also, chemiotaxis and phagocytosis are regarded as specific cell actions for the "purpose" of assisting the individual in dangerous invasions. In other words, something is read into natural phenomena which has no relation to causal relations or connections. What is worse, however, is that these purely personally assumed metaphysical attributes are now employed—it is really terrible to acknowledge it in the twentieth century—to *explain* natural phenomena. Thus, we read that a "toxin stimulates to the formation of an antibody," and in one modern text-book on pathology, I find "inflammation" compared to the activities of a fire-brigade! Consider what all this means. An unknown assumed quality is employed to furnish us with scientific understanding of other unknown qualities, that is, one unknown explains or is intended to convey to our understanding another unknown, like Baron Münchhausen, who, having got stuck in a swamp, lifted himself by his own hair out of it. And who can help being reminded here of the old one-sided rationalism of the earliest scholastic period which saw in universal ideas realities of independent existence.

(The scholastic period passed, as well known, through three stages, the first and most brilliant assumed the reality of ideas, that is, of universals, *before* things. It is expressed in the phrase "*Universalia sunt realia*" or, "*ante rem.*" The second modified this to "*Universalia sunt in re,*" that is, they *lie* in *things.* The third, finally, which inaugurates the disintegration of scholasticism, assumed only "*Universalia sunt nomina*" or "*post rem,*" that is, they are simply names of common properties (Nominalism)).

This conception and acceptance of pathological entities, not as convenient names of categories, but as an expression of the independent nature of things which are dictated by teleological demands, still control in too large a measure the minds of the medical profession. Thus, through a deplorable lack of philosophical training, medical science stands at present a monstrous anomaly of causal, etiological, symptomatic and transcendent ideas. And thus it has been plunged into a hopeless muddle of definitions and classifications. For this reason I have long insisted that in order to create clearness out of chaos, we should frame our definitions and classifications in pathology, when they fall short to establish causal connections of phenomena, according to unbiased objective (anatomical) descriptions.[3] Helmholtz, the physicist and one of the great experimental physiologists, around the middle of the last century, exclaimed, "Return to Kant." In his great critique of judgment, Kant said, "The purpose [meaning the transcendent power] is a stranger in the natural sciences." And thus he insisted that nature, in order to be intelligible at all, must be explained *physically* through the *intellect.* But Kant also clearly saw that human mind possesses something besides intellect, and thus, while the world is *explained physically* through intellect, it is *interpreted metaphysically* by man's will. Thus Kant properly divides with finest acuteness and with a magnificent grandness of criticism what is intellectual, physical and explanatory in life from what is personal in will and character and assumed. *For the latter does not explain at all but interprets.* It may, therefore, *never substitute for the other* in the *explanation* of things. But even when we resort in the final instance to metaphysical interpretation, we must nevertheless bear in mind that this does not allow any purely imaginary fantastic system, it may not run rampant, but even metaphysics must harmonize, as Wundt insisted, with our intellectual qualifications. Thus Wundt lifted even metaphysics from the position of dreams to a justified philosophical constituent.

The science of pathology and medicine to-day are in bad shape for the reason that their followers are still largely unscientific and

[3] This stand has also long been advocated by Thoma and more recently by Ricker, especially in regard to the inflammatory conception.

not philosophically trained.[4] Sciences atrophy and degenerate when they lose contact with philosophy. Physiology has already permitted light to enter. We find in biophysics a genuine attempt to penetrate through the causal mechanism and to explain construction and functions of the normal living body, according to biophysical laws. Compare the fantastic ideas of Metchnikoff on cell activity with the clear-cut explanations of Rhumbler! Here pathology and even the practice of medicine must follow. Even the practitioner of medicine must be clear in his mind what is meant by logical cause and sequence and what is an auxiliary conception which simply summarizes or interprets but can never explain. He will, then, be less liable to fall for high-sounding therapeutic preparations, or for the rapid practical application of scientific discoveries still under discussion. But he will be better able to properly interpret symptoms and findings in his patient, and he will understand principles of treatment. Until this more profound, philosophical attitude of mind is developed in the practitioner, he will have to compete with osteopaths and chiropractitioners. For he is as crudely empirical, and, therefore, as helpless, as they are, in scientific understanding and treatment of disease. What every practitioner of medicine really needs to-day more than anything else is sound critical judgment of values. He shares that need with almost everybody else in this democratic period. He must every day weigh evidence, which confronts him in his patients and in all the scientific and therapeutic propaganda which meet him daily at the breakfast table through mail and newspapers and by agents in his office. How is he to get judgment of values? There is only one answer! At present, as in the past, not by stuffing him with pseudo science, or feeding him on practical dishes, cooked out of specially prepared scientific food, but through a philosophical consideration and understanding of *all* things, which prepare him to follow and understand independently his own experience and that of others.

The world is everywhere this year celebrating the 200th anniversary of the birth of Immanuel Kant. No other philosopher of recent times has perhaps exercised such deep and beneficial influence on the sciences. As a pathfinder of correct scientific thought and reasoning we owe him the heaviest debt. I offer this as a tribute to him and to the importance of his teaching not only in his own branch but in all spheres of human understanding and knowledge.

[4] Witness the grotesque modern attempts to trace complex *psychic phenomena* directly to the influence of *individual internal secretions* and thus to control them! The abuse of the whole matter of internal secretions has recently been well criticized by J. Bauer, of Vienna. (Individual Constitution vs. Endocrine Glands. Bullet. Buffalo General Hospital. I. 3. 1923.)

THE PHYSICAL BASIS OF DISEASE

By THE RESEARCH WORKER

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IV TISSUE OVERGROWTH

"If you wish," said the research worker as the group reassembled in the lawyer's compartment the next morning, "we will take up a fourth group of diseases this forenoon."

"Nothing to do but kill time till we reach Ogden," replied the lawyer.

"I believe you have the right dope as to the kind of facts that should be given the general public," added the manufacturer.

"As our fourth group of diseases, then," continued the research worker, "let us select diseases due to excessive tissue growth in important organs or parts of the human body.

"Probably the simplest example of tissue overgrowth is an ordinary wart. If you cut open a wart and examine its cut surfaces with a magnifying glass, you will find that the wart is composed of an excessive growth of the outer layers of skin. This excessive epithelial growth may form a fairly smooth raised patch on the skin or it may be thrown into folds, forming finger-like or cauliflower-like projections from the skin Relatively little is known as to the cause of warts. They are probably due to some infectious agent. Wart juice transferred to normal skin will frequently cause warts."

"Then you don't endorse our boyhood fancy that warts are caused by handling toads," said the lawyer.

"You'd be surprised at the number of adults in certain rural communities who are firmly convinced that toads do cause warts. It's a typical example of popular medical ideas based on superficial resemblance. During my boyhood I am sure I never touched a toad until after I had developed a fairly extensive crop of warts. Due to my boyhood reactions to adult warnings, I frequently handled toads after that date. My crop of warts rapidly disappeared."

"Toad homeopathy," said the lawyer. "You should have commercialized your discovery."

"Fortunes are being made to-day by the manufacture and sale of alleged remedies that have originated in a manner similar to this. With a sufficiently aggressive advertising campaign, toad-skin extract undoubtedly could be made commercially profitable."

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"A slightly more complex example of skin overgrowth is furnished by skin cancers. You have undoubtedly seen numerous individuals with skin cancers, spreading ulcers of the lips or face or other parts of the body. If this skin growth is cut open and its cut surfaces examined microscopically, it will be seen to be composed of an excessive growth of the deeper layers of the skin. This cancerous growth differs from that of ordinary warts in that the finger-like or cauliflower-like processes do not extend outward from the skin surface as in warts, but extend downward and penetrate into the underlying parts. These downgrowths of atypical epithelium gradually kill the underlying tissues into which they penetrate. The nutrition of all but the deeper layers of the cancerous growth is defective, so that the outer portions of the cancer usually die and are sloughed off, leaving the chronic ulcer or open sore with which you are familiar.

"Minute fragments of the finger-like epithelial downgrowths may be detached from the main cancer mass and carried to distant parts of the body. Here they may continue their growth, forming new cancer masses. These secondary cancers may penetrate and destroy important internal organs. Death from skin cancer is usually due to the destructive action of these secondary cancers on important internal parts."

"I have read somewhere that cancer is becoming much more frequent," said the lawyer.

"I believe the number of deaths from cancer in the United States is at present approximately equal to that from tuberculosis. I am not certain, however, that this means a real increase in the prevalence of cancer. Cancer is essentially a disease of advanced age. The average length of life has been materially increased during the last few decades. One would expect statistics to show an apparent increase in all diseases of the later period of life.

"The cause of skin cancer is not known. Hereditary predisposition, chemical injury and mechanical injury are undoubtedly contributory factors. The essential exciting agent, however, is unknown."

"Are there any real cancer cures?" asked the manufacturer.

"No successful therapeutic agent has thus far been found for human cancer. Cancer tissue is less resistant than normal tissue to X-ray and similar agents. Certain external cancers can be successfully killed by X-ray without undue injury to the surrounding normal parts. This method is not generally applicable, however, to more delicate internal organs. The only dependable cancer cure is radical surgical removal. If done early in the disease, before sec-

ondary internal cancers are formed, it is a successful method. After invasion of internal organs, however, cancers are practically incurable. Numerous alleged cancer cures, however, are on the market."

"I have an acquaintance who had cancer of the stomach," said the manufacturer. "She was cured by such a remedy."

"I will wager any amount of money that the facts of the case are not as you have understood them. The facts are probably about as follows: You have an acquaintance. She had certain symptoms. She thought these symptoms came from her stomach. In some way she got the idea into her head that she had cancer. She purchased six bottles of an alleged cancer cure. Two months later her symptoms disappeared She then claimed she had been cured of cancer. Hundreds of such claims have been investigated. There is not a single authentic case on record of a cancer cured by a commercially exploited remedy. Thousands of autopsy records substantiate this conclusion. The same thing is true of the numerous alleged cures of cancer by the various forms of religio-therapy."

"In addition to local skin overgrowths illustrated by warts and cancers, there are numerous examples of excessive growth of the skin as a whole. One of the best illustrations of this takes place following the surgical removal of the thyroid gland. In these cases the skin becomes markedly coarsened in texture, and greatly increased in thickness The face becomes puffy and expressionless. On microscopic examination the increased thickness of the skin is seen to be due to a general overgrowth of the deeper skin layers, with jelly-like deposits in these layers.

"This skin overgrowth can be arrested, and usually the skin restored to normal by the administration of thyroid extract. This skin overgrowth is therefore but one effect of insufficient amounts of thyroid gland in the body."

"It doesn't seem credible," said the manufacturer, "that a small gland in the neck can produce such marked changes in such a tough structure as the skin."

"A small amount of iodin is present in all living plants and animals. Iodin is apparently necessary for the normal growth of all human tissues, including the skin. If we look upon the thyroid gland as the main organ in which iodin, taken in as food, is prepared for the use of other tissues, we can understand how disturbed thyroid function can influence skin growth. Whether or not this conception is in accord with the actual chemical facts of the case has not been fully determined."

"I should think that would be a problem very easily settled by an expert chemist," said the lawyer.

"This problem is typical of numerous unsolved problems in research medicine. Rapid progress would be made in the solution of these problems if there were adequate financial support and social recognition for research workers. Most of the important scientific advances of the past have been made by young men during the few years necessary to build up a practice or obtain other remunerative employment. Very few mature medical workers have been able or willing to continue in the research field.

"Except in Germany," said the manufacturer.

"Germany's former world lead in certain lines of medical research was mainly due to the official honors and social recognition given to research workers. Mature men of high attainments were attracted to this field.

"We surely ought to interest some of our American live wires in this game," said the manufacturer.

"The typical 'live wire' is useless as a research worker. He's equally unsuccessful as a director of research. A quite different type of man has been responsible for the important scientific advances of the past."

"How about K——?" asked the lawyer. "The papers are full of his discoveries."

"Very successful in selling himself to the general public. His spectacular results, however, almost without exception have been quietly disproved by competent laboratory workers. One must discount 95 per cent. of all medical discoveries announced in the daily press.

"There are numerous other examples of tissue overgrowth in one part of the body resulting from abnormal activity of a remote gland. One of the most striking of these is excessive growth of the bones that occasionally takes place, enormous enlargements of the hands and feet, and weird distortions of the features. This is the disease known technically as acromegaly. There is conclusive evidence that the excessive bone growth in this disease is due to overactivity of a small gland at the base of the skull, the pituitary gland. This gland apparently forms or secretes substances that serve as normal stimulants to bone growth. Partial removal of the pituitary gland in early life results in a stunted growth of the bones, the formation of dwarfs. These effects have been extensively studied on animals.

"Excessive bone growth, however, can apparently be produced in other ways. A familiar example is the enlargement and distortion of the joints in certain types of 'chronic rheumatism.' The cause of these joint enlargements is not known."

"I thought rheumatism was a germ disease," said the manufacturer.

"The term 'rheumatism' is popularly applied to numerous diseases giving pain in the joints or extremities. Certain forms of rheumatism are due to infectious agents. The cause of the excessive bony overgrowths in the form of chronic rheumatism I have in mind, however, is unknown. Autopsies indicate that the bony overgrowth is probably not dependent upon pituitary abnormality. The disease has never been reproduced in lower animals, hence little progress has been made in discovering the real cause."

4

"Tissue overgrowth is one of the commoner forms of disease in internal organs. A good example is the formation of wart-like processes on the heart valves. These finger-like or cauliflower-like outgrowths on the valves are usually the result of the local action of disease-producing microorganisms The wart-like masses may be so large as to seriously handicap the heart, either by interfering with the forward passage of blood or by preventing the normal closing of the valves so that backward leakage takes place.

"One of the serious dangers arises from the tendency of these wart-like masses to rupture. Small fragments of the mass may plug important arteries in other parts of the body. Autopsies in cases of such valvular outgrowths often show large areas of important organs killed, liquefied, partly absorbed or partly or completely replaced by scar tissue as a result of the plugging of local arteries. Paralysis or sudden death may result from the plugging of certain brain arteries.

"Probably the most common tissue overgrowth in the circulatory system, however, is excessive tissue growth in the walls of the blood vessels. The delicate lining of the blood vessels is often stimulated to excessive growth by the action of toxic or infectious agents. The lining may become several times its normal thickness.

"This increased thickness of the lining of the blood vessels is without appreciable mechanical effects in the larger arteries. In the smaller blood vessels, however, the increased thickness materially narrows the blood vessel and may even lead to its occlusion. In this way numerous minute blood vessels may be reduced to solid cords, through which blood can not circulate. This greatly reduces the nutrition of the parts supplied. It usually leads to marked degeneration of these parts. The degenerations of the nervous system in late stages of syphilis, for example, are often due to partial starvation and asphyxiation of the nerve cells from such blood vessel narrowing."

"I wonder if many people realize that syphilis can cause such changes as this," said the lawyer.

5

"Numerous examples of tissue overgrowth are found in the respiratory system. One of the most striking of these is the formation of secondary cancer nodules in the lungs. Small fragments of skin cancer, for example, may be carried to the lungs and there lodge in the minute blood vessels. These minute cancer fragments may continue to grow in their new location. They gradually penetrate and destroy the surrounding lung tissue. It is not uncommon at autopsy to find a lung containing a hundred or more cancer masses varying in size from a pea to that of a small orange.

"An interesting example of tissue overgrowth in the lungs takes place in syphilis. Here the walls of the air sacs may be thickened by excessive tissue growth. This overgrowth greatly reduces the size of the air spaces and may even lead to their obliteration. The thickened walls also interfere with the normal interchange of oxygen between the circulating blood and the inspired air."

"Tissue overgrowth is also common in the digestive system. Wart-like masses, for example, may form in almost any part of the gastro-intestinal tract. They are often so large as to seriously interfere with the passage of food.

"Probably the most important tissue overgrowth in the gastro-intestinal tract, however, is cancer formation. A frequent site of primary cancer is the junction of the stomach and intestine. Autopsy will usually show this junction changed to a solid mass of cancer tissue, firmly attached to adjacent organs. On cutting open this mass, the passage from the stomach to the intestines is usually found markedly narrowed, even completely obliterated.

"Aside from mechanical interference with the passage of food, a fairly common effect of cancer growth in this locality is mechanical interference with the excretion of bile. The bile duct, as you know, enters the intestine near its junction with the stomach. This duct is often narrowed or compressed by the cancer mass. This causes a damming back of the bile into the liver, with its absorption by the circulating blood. The yellowish pigmentation of the skin often seen in such cases is usually due to such bile absorption."

"What's the real dope on the surgical treatment of such cancers?" asked the manufacturer.

"If gastric cancer is recognized at an early stage, before it sets up secondary nodules in surrounding parts, the cancer growth can often be completely removed, with fair chances of a permanent cure. After invasion of surrounding organs, however, it is often impossible for the surgeon to find or to remove all the cancer frag-

ments. The minutest unremoved fragment will eventually cause death of the individual.

"A somewhat different example of tissue overgrowth in the digestive system is giantism of certain portions of the gastro-intestinal tract. Giantism, for example, is fairly common in the stomach. A stomach may be so enlarged as to almost completely fill the abdominal cavity. Or, it may be of approximately normal size, but with walls several times the normal thickness. A frequent cause of stomach giantism is increased resistance to the passage of food from the stomach to the intestines. The enlarged stomach is usually more or less incapable of causing proper movements of the food. Stagnation, fermentation and putrefaction of food may take place."

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"Very striking symptoms may be caused by tissue overgrowth in the nervous system. A good example of such overgrowth is an increase in the thickness of the meninges or sheath surrounding the brain and spinal cord. This sheath, for example, is occasionally locally thickened, forming a firm ring or collar about the spinal cord. This collar may so constrict the spinal cord that degenerations and even death of the underlying nerve cells take place, causing various sensory disturbances and paralytic symptoms.

"The commonest tissue overgrowths in the nervous system, however, are tumor masses. These usually arise from the supporting tissues of the brain or spinal cord, rather than from the nerve tissue itself. The tumor masses mechanically compress and irritate adjacent parts, causing nerve cell degeneration and in extreme cases nerve cell death. Our present knowledge of brain localization has been largely derived from a comparison of the clinical symptoms and subsequent autopsy findings in such cases. One of the common effects of such tumor masses is increased pressure within the skull cavity. This mechanically interferes with the circulation and nutrition of the brain.

"Cases are on record of marked overgrowth of the brain as a whole. I am not certain that microscopic examinations were made in these cases. I do not know whether the increased brain weight was due to a real overgrowth of nerve tissue or was only an apparent increase from excessive amounts of fluid and supporting tissues. I believe the largest brain on record weighed over twice that of a normal individual. It was the brain of an idiot."

"We must be entering the outskirts of Ogden," said the manufacturer.

"Our last real breathing spell before we reach the coast," said the lawyer.

OCCUPATIONAL DIFFERENTIAL FECUNDITY

By HORNELL HART

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CERTAIN eugenists have taken a highly alarmistic attitude toward the future of the race. Thus C. S. Saleeby writes of British conditions:

> A steadily and rapidly diminishing proportion of the nation's children are being born to parents, and in environments, such as promise them the best inheritance, both biological or genetic, and social. . . . Evidently a very very few generations of this, which is typical of the whole nation, must be fatal. School clinics are blessed and precious things, but they are less than a forlorn hope in such a racial tragedy as this. . . . I believe that, if this practice (race suicide) continues, our race in these islands is doomed.

Similarly pessimistic as to America is Lothrop Stoddard. He says:

> If intelligence continues to be bred out of the race at its present rate, civilization will either slump or crash from sheer lack of brains.

The argument used by the eugenists involves four steps, which may be summarized as follows:

(1) The more highly educated classes, the professional classes, and the more successful business classes are reproducing at much lower rates, and with longer intervals between generations, than are the unskilled, ignorant and poverty-stricken classes.

(2) The highly educated, professional and more successful business classes average far higher in desirable characteristics—particularly in intelligence and energy and in the capacity to provide wholesome child environments, than do the unskilled, ignorant and poverty-stricken classes.

(3) These desirable characteristics are transmitted from parents to children through social and biological heredity.

(4) From the above premises it would follow that average intelligence and average social desirability in general, in so far as they are socially hereditary, will have a strong *tendency* to decline and in so far as they are *biologically* hereditary will be *bound* to decline from generation to generation until the disgenic differential fecundity of these classes is altered. Put into other words, the conclusion derived from the above premises is that the rapidity of human reproduction is inversely correlated with the quality of the

germ plasm, and inversely correlated with the quality of the culture of the individuals reproducing, and that this inverse correlation means progressive deterioration of the race.

If this conclusion is justified it far outshadows in ultimate significance the great majority of problems to which humanitarians and social research workers give attention. Yet, although great quantities of statistics have been collected on differential fecundity, there seems to be available no reliable quantitative estimate of the speed with which the race is approaching its disgenic doom. The specific question which needs a definite answer is: how much decline in racial quality is occurring per decade through differential fecundity?

Because of gaps and defects in existing data, no adequate answer can be given to this broad question. The present paper attempts to indicate the answer to a narrower query; namely, how much lower in ability to pass mental tests is the rising generation than it would have been if fathers in various occupations had had the same average number of surviving children? What is the effect (in other words) of occupational differential fecundity upon the mental-test ability of the rising generation?

With regard to the fact that the higher occupational groups are reproducing much more slowly than the lower occupational groups, comprehensive and fairly conclusive statistics have recently become available for the United States registration area, in the census analysis of data from birth certificates for 1920. From these tabulations it is clear that the wives of men in the least skilled occupations not only have had decidedly more children born to them than the wives of more highly skilled and better educated men have, but the number of *surviving* children in the lower occupational groups is markedly greater than the number in the higher occupations.

These tabulations by the United States Census Bureau are based upon such large numbers of cases that the contrasts which they show in fecundity between occupations can not be due to chance. It is a striking fact, moreover, that data collected in Scotland, by different methods, at a different date, strongly corroborate these figures relating to the United States. For 39 comparable occupations the correlation between the number of children born per wife in these American families and the number born per completed marriage in Scotland, is plus .84 with a probable error of .05. This high correlation indicates that, in spite of the differences between social conditions in Scotland and in the United States, and between the statistical methods employed, the data for the two countries correspond with each other to a surprising degree. The

sizes of families for certain important occupations are shown in Table 1. In both America and Scotland the better educated and

TABLE I

FECUNDITY AND OCCUPATION

In Scotland and in the United States

Occupation	Average number of children born *Scotland* (Completed families)	*U. S* (Uncompleted families)	Average number of living children *U. S.*
Professional			
Dentists	3.9	2 0	1.9
Technical engineers	4.4	2 1	1.9
Teachers	4.2	2 3	2 1
Lawyers	3.9	2.4	2.2
Clergymen	4.3	3.3	3 0
Mine owners	6.4	3 2	2 9
Skilled workmen			
Electricians	5.0	2.3	2 1
Printers	4.9	2.5	2 3
Plumbers	5.4	2.8	2.5
Painters	5.6	3.3	2.9
Carpenters	5.6	3 5	3.1
Rural			
Farmers	6.2	3.8	3.4
Agricultural laborers	6.4	3 5	3.0
Unskilled laborers			
Garbage men	6 2	3.4	2 9
General laborers	6.3	3.7	3.1

The sources of data for the above table are: Dunlop, James Craufurd, "The fertility of marriage in Scotland," *Journal of the Royal Statistical Society*, 77 (1914), 259–288; United States Census, Birth Statistics, 1920, p. 18.

more successful occupational groups have decidedly fewer children born. Laborers' families in both countries have from 50 to 100 per cent. more children than the families of professional men. It is true that clergymen in the United States have nearly as large families as laborers, and that mine owners in both countries have strikingly large families. In general, however, it seems clear, as a great many other statistical studies have indicated, that the occupations requiring the longest educational preparation have the smallest families.

The next step in the inquiry is to determine what differences, if any, exist in the mental-test ability of the children having fathers in the various occupational groups. The term "mental-test abil-

ity'' is used in this paper instead of the term ''general intelligence.'' The problem of what mental tests really measure is not involved in this argument. Whether the ability to get high scores in these tests is due to innate excellence of one's brain cells, or to the excellent vocabulary and the training given by one's parents, the arguments and conclusions of the present discussion are equally valid. There is a fairly specific sort of ability measurable by mental tests, and known to be important in connection with success in life. Is the mental-test ability of the American people declining as a result of differential fecundity between occupations? If so, how rapid is the rate of that decline?

Several independent investigations throw light upon the differences in the mental-test ability of the children of fathers in different occupational groups In the three cities in which are located the universities of Ohio, Indiana and Wisconsin, studies have severally been made by psychologists from those universities to determine the comparative abilities of the children of men of different occupational levels. In each of the three studies the children of professional men average by far the highest in mental-test ability, the children of business men next highest, skilled workmen's children next and the children of unskilled laborers lower than any of the above three occupational groups. The Indiana study places children from rural districts distinctly lower than children of unskilled laborers, but the investigation included an abnormally poor rural area. The Wisconsin study puts the children of farmers markedly higher than those of unskilled laborers, but the number of farmers' children tested in that study was only 60, and there is some reason to think that the children of farmers attending school in Madison may be a selected group. An intensive study of a typical rural area by the Iowa Child Welfare Research Station places the children of farmers slightly higher in intelligence quotient than the children of unskilled laborers. The results of the Indiana, Columbus and Madison studies are summarized in Table 2.

Although these three studies were made in different states, with different tests, by different investigators and although the results are stated in quite different statistical units, the conclusions reached are strikingly unanimous. There can be no question that the occupational groups with higher standards of living and smaller families do produce children with decidedly higher mental-test ability on the average than the occupational groups with lower standards and larger families.

On the basis of the data thus far presented it must be conceded that disgenic differential fecundity between occupations does exist. Table 3 brings together for the broad occupational groups the sizes

TABLE II

CHILDREN'S MENTAL-TEST ABILITIES IN RELATION TO FATHERS' OCCUPATIONS

Occupations	*Indiana* study	*Columbus* study	*Madison* study
Professional	83	1.42	114
Business	66	1.26	104
Skilled trades	47	1 22	97
Unskilled labor	39	.83	89
Farming	27		94
Number tested	1,206	228	2,782

The statistical units employed in the above studies were: in Indiana the percentages of children above the median scores for their ages in the Pressey tests; in Columbus the coefficient of mental ability based on the Yerkes-Bridges Point Scale; in Madison the intelligence quotients based on the Dearborn and National Intelligence Tests.

The sources of the data in the above table are: Pressey, S. L., Luella, W., and Thomas, J. B, "A study of country children," etc, *Journal of Applied Psychology, 3* (1919), 283–286, *4* (1920), 91–96; Pressey, S. L., and Ralston, Ruth, "The relation of the general intelligence of school children to the occupation of their fathers," *Journal of Applied Psychology, 3* (1919), 366–373; Bridges, J. W., and Coler, Lillian E, "The relation of intelligence to social status," *Psychological Review, 24* (1917), 1–31; Dexter, Emily Smith, "Relation between occupation of parents and intelligence of children," *School and Society, 17* (1923), 612–616

TABLE III

DECLINE IN MENTAL-TEST ABILITY

Due to Occupational Differential Fecundity

Occupations	Average Number of *Living Children*	*Average I. Q.* of Children
Professional	2 2	114
Business and clerical	2.5	104
Skilled trades	2.6	97
Farming	3.4	91
Unskilled labor	3.1	89
Average I. Q. of families		94.3
Average I. Q. of children		93.7
Difference due to differential fecundity		.6

of families and the average intelligence quotients of the children. The figures therein shown are weighted averages built up from finer occupational classifications. From the data here summarized it is possible to get a first approximation of an answer to our question as to the effects of occupational differential fecundity upon American intelligence. Suppose that we enter for every family that reported having had a baby in the registration area in 1920 the average intelligence quotient of children having fathers in cor-

responding occupations. If these intelligence quotients are added up and divided by the total number of families reporting births, the result will be the best available estimate of what the average mental-test ability of the children of these fathers would have been if the average size of families in the various occupations had been uniform. This average intelligence quotient, which counts each family only once, is 94.3 If we assign to *each living child* of the fathers reporting babies in 1920 the intelligence quotient found for children of fathers in corresponding occupations, and divide the total of these intelligence quotients by the total number of living children, the result will be the best available estimate of the mental-test ability of the living children of these fathers under actual conditions This average is 93 7 The difference between these two averages is six tenths of one point I Q. In other words, the average mental-test ability of the living children of these fathers is six tenths of one point lower, in terms of intelligence quotients, than it would have been if every occupation had had the same average number of living children per father.

While the above method gives a first approximation of an answer to our question, it involves certain statistical imperfections and it fails to reflect the full effect of differential fecundity because it takes into account only *occupational* differences in size of families. It is just as significant if brilliant lawyers have smaller families than stupid lawyers and if intelligent laborers have smaller families than stupid laborers as it is if lawyers have smaller families than laborers. Comparisons *within* occupational groups are just as significant as comparison *between* occupational groups. Differential fecundity between families is the important thing to measure. The occupational group is merely a somewhat clumsy statistical intermediary for arriving at approximate results.

To avoid these difficulties involved in the method of occupational differential fecundity, the writer is now making a survey of 500 typical families in Davenport, Iowa, in which the number of surviving children in approximately completed families will be correlated with mental-test ability, school progress and certain very carefully determined measures of important character traits. When a sufficient number of such studies have been completed in typical American communities they will make available for the first time accurate quantitative data for answering the question as to the effects of differential fecundity upon racial quality in this country.

In the meantime it can be said with confidence that differential fecundity between occupational groups is having a rather slight, but unquestionable, depressing effect upon the mental-test ability of the rising generation in the United States.

HIGHER MENTAL AND PHYSICAL STANDARDS FOR IMMIGRANTS

By Professor ROBERT DeC. WARD
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FOREWORD

THE Immigration Act of 1924 established a new American immigration policy. It marked "the passing of the dominating factor of economics and established for the future American policy the basic elements of racial values and family stock quality."[1]

Within certain limits, which are rather vague because of an at present unknown number of "non-quota" immigrants, we have decided to admit only a limited number of new aliens, and the bulk of these are to be of the same racial stocks as those which originally settled and developed our country, founded our institutions, framed our constitution and to-day still make up the bulk of our population. Until we had set some sort of numerical limitation on immigration, better selection—mental, physical or economic—was impossible. That very important first step having finally been taken, it now becomes our duty, both to ourselves and to coming generations of Americans of whatever racial origin, to set higher mental and physical standards for all our future immigrants. It is an absolutely illogical and indefensible situation that our regulations governing the admission of animals and plants are to-day, and have been for years, far more stringent than our immigration laws, and have been more strictly enforced.

It is the aim of the present paper to consider briefly: (1) what legislation has already been enacted to exclude eugenically undesirable immigrants; (2) how these laws have worked, and (3) what further amendments have been suggested in order to bring about a better selection of immigrants on mental and physical grounds.

THE GENERAL IMMIGRATION ACT OF 1917

The general Immigration Act of 1917 enumerates all the classes of aliens which Congress has so far declared shall be excluded because eugenically undesirable. In respect to these classes the act of 1917 remains in force, not having been superseded by the new act of 1924. The aliens thus specifically debarred under Section 3 are the following: idiots, imbeciles, feeble-minded persons; epileptics;

[1] *Eugenical News*, July, 1924.

insane persons; persons who have had one or more attacks of insanity at any time previously; persons of constitutional psychopathic inferiority; persons with chronic alcoholism; persons afflicted with tuberculosis in any form or with a loathsome or dangerous contagious disease; persons not comprehended within any of the foregoing excluded classes who are found to be and are certified by the examining surgeon as being mentally or physically defective, such physical defect being of a nature which may affect the ability of such alien to earn a living. In order to prevent so far as possible the bringing or landing of any aliens belonging to the above excluded classes, certain fines are imposed upon the transportation companies in cases of violation of the law, if it appears to the satisfaction of the secretary of labor that any alien so brought was afflicted with any of the specified diseases or disabilities at the time of foreign embarkation, and that the existence of such disease or disability might have been detected by means of a competent medical examination at such time In addition, the company has to pay a sum equal to that paid by the alien for his transportation from the initial point of departure to the port of arrival.

In order to determine whether any alien belongs to any of the excluded classes such alien may be kept on board ship or at an immigration station long enough to enable the medical officers to reach a definite conclusion in the matter.

The act specifically and definitely provides that the decision of a board of special inquiry (which acts on the cases of all aliens who do not appear to the examining inspector to be clearly and beyond a doubt entitled to land) "shall be based upon the certificate of the examining medical officer, and, except as provided in Section 21, shall be final as to the rejection of all aliens afflicted with tuberculosis in any form or with a loathsome or dangerous contagious disease, or with any mental or physical disability which would bring such aliens within any of the classes excluded from admission to the United States under Section 3 of this act."[2] These are known as the *mandatorily excludable* classes. Section 21 here referred to as containing the exceptions, *i. e.*, as specifying the only cases in which the certificate of the medical officer may not be final as the cause of debarment, provides that any alien liable to be excluded because (1) likely to become a public charge, or (2) because of physical disability other than tuberculosis in any form or a loathsome or dangerous contagious disease, may be admitted in the discretion of the secretary of labor upon the giving of a suitable bond. The only appeal of an alien certified for insanity or mental defect is to a board of medical examiners (Section 16). Appeals from the

[2] Section 3 names the excluded classes, as above indicated.

ordinary decisions of the boards of special inquiry are to the secretary of labor. Every adverse decision may be thus appealed. Section 19 provides that aliens who at the time of entry belonged to one or more of the classes excluded by law, or who entered the United States in violation of the law, shall, upon the warrant of the secretary of labor, be taken into custody and deported.

These are the specific provisions of our immigration law with reference to the exclusion of eugenically undesirable aliens.

Why Eugenically Undesirable Aliens have not been more Effectively excluded

Complete and satisfactory as the act of 1917 seems to be, it has not accomplished its purpose. *It has not in the past been rigidly enforced.* Every one who is at all familiar with immigration problems knows that, and especially the aliens themselves, their relatives and friends in this country and the steamship companies. There have been admitted not hundreds but thousands of aliens who were diseased; who were mentally and physically far below par; who had criminal records and tendencies; who could not earn their own living; who were in every way hopelessly undesirable and impossible material for American citizenship.

There have been three main reasons why the many excellent eugenical provisions in our immigration law have not been enforced. These are (1) the lack of enough thoroughly competent and well-paid inspectors; (2) the impossibility of detecting, in the usually hurried and superficial examination at the port of arrival, nearly all the cases which for one reason or another should be debarred; (3) the abuse of the privilege of appeal from the decision of competent medical officers and of the boards of general immigration inspectors, and the far too great leniency in sustaining such appeals in the office of the secretary of labor.

The decrease in numbers and the improvement in quality of our immigrants which will result from the new Immigration Act of 1924 should help greatly to make the medical examination of arriving aliens more thorough, and thus lead to the detection of more of those who belong in the mentally and physically defective classes. In other words, the difficulties noted under (1) and (2) above ought to be lessened. The third difficulty, noted under (3), will remain unless those who are concerned about the future mental and physical condition of our people take hold of this problem and see to it that what has happened in the past shall hereafter no longer be possible. The appeal and bonding clauses of the act of 1917 give the secretary of labor authority, in his discretion, to reverse the decisions of the boards of special inquiry, and also to permit aliens

suffering from certain diseases or disability, or likely to become public charges, nevertheless to enter the United States for a limited time, under bonds, for treatment or observation, or to give them opportunity to prove that they will not become public charges. In theory, this is a very humane and just provision. In the opinion of unprejudiced students it is one of the biggest holes in our general immigration law. Under these clauses far too many aliens mentally and physically defective and certain to become public charges have been admitted. Appeals are constantly made on behalf of every class of alien specified in the law as excludable. Immigrant "aid" and charitable societies; immigrant lawyers who prey on the alien; relatives and friends of those liable to be debarred; senators and congressmen of the United States and city and state politicians more interested in securing a few votes from their foreign-born constituents than in the future character of our race, misguided sentimentalists, appeal in behalf of the detained alien. The United States usually has everything to lose and nothing to gain if the appeal is sustained The only safeguard which the country has is in the honest and patriotic officials of the Immigration Service, who, in the face of terrific pressure, endeavor to uphold the law. The result has been that aliens certified by thoroughly competent expert medical officers as having such mental or physical defects as constitute them potential public charges and highly undesirable elements in our population have been admitted, on appeal or under bonds. As Hon. Robert E. Tod, recently commissioner of immigration at Ellis Island, has said, "It is an insult to the intelligence of the examining boards of medical officers to reverse their decisions over and over again under political pressure."

The situation regarding aliens who are certified as having physical defects which in the opinion of the medical officers may affect the ability of the alien to earn a living needs a few words of comment. The provision adding to the excluded classes (1907) those certified as being mentally and physically defective, the defect being of such a nature as to affect ability to earn a living, has proved of comparatively little value eugenically. Those who drafted this provision intended it to be a medical test, but it was very soon decided that the medical certificate in such cases was only one piece of evidence to be taken account of by the board of special inquiry as bearing on the question of the ability of the alien to earn his living. In other words, the provision became an economic, not a medical test. Most of the cases admitted on appeal have been those of aliens with a medical certificate of this character, but where other circumstances seemed to warrant admission.

The remedy for this situation is obvious: (1) No immigrants belonging to the class of *mandatorily excludable* aliens (*i.e.*, those

suffering from idiocy, insanity, imbecility, feeble-mindedness, epilepsy, constitutional psychopathic inferiority or chronic alcoholism) should ever be admitted.[3] (2) There should be no yielding to political pressure for the admission of aliens on appeal over the decisions of the medical examiners and the boards of special inquiry. As a recent writer has said, "any intervention by a politician in behalf of an excludable alien should be regarded as a strong presumption that the case should be dropped at once, and the alien deported forthwith" (3) The whole policy of admitting aliens who are not *clearly* and *beyond question* entitled to land—border-line cases—must be stiffened up all along the line. Appeals from adverse decisions of the boards of special inquiry should rarely be sustained. Aliens suffering from a physical or mental disability which makes them potential public charges should always be excluded unless there are very strong reasons to the contrary. The appeal and bonding provision as it stands at present can be, and has been, used to nullify many of the excellent eugenical clauses of the law. American public opinion must arouse itself and insist on a rigid enforcement of this law As things now stand, alien interests and alien influences and alien "pressure" working—to their shame be it said—through American senators and congressmen are active day and night to secure the admission of immigrants whom Congress has declared inadmissible.

One reason for the laxity in the enforcement of the law is that there is a very widespread idea that "the United States should not separate the families of aliens" when an imbecile or a feeble-minded or other excludable member of the family arrives at our ports. But it should be remembered that in the large majority of such cases, the alien family intentionally separated itself overseas, when some members of the family, knowing perfectly well the provisions of our law, came over first, established a foothold, and then sent for the feeble-minded or imbecile or diseased son or daughter, mother or aunt, uncle or nephew. The vast majority of our immigrants know our immigration laws far better than most Americans do and deliberately "work" the sentimental plea in favor of the admission of the undesirable child or relative. It is very easy to arouse tremendous sentiment in individual cases of apparent hardship. A brief paragraph in a daily newspaper is all that is necessary to bring that about. The far larger interests of the United States, which suffer through the admission of mentally and physically unfit aliens, are more remote, and hence attract little or no attention.

[3] Recommendation of Interstate Conference on Immigration, New York, Oct. 24, 1923.

The Immigration Act of 1924

Although the Immigration Act of 1924 contains no specific provisions looking towards a more rigid exclusion of eugenically undesirable aliens, it will accomplish a better selection than has hitherto been possible. It will accomplish much more than a change in the racial character of our future immigration, tremendously important as that change will be. It will also bring about a distinct improvement in the mental and physical conditions of our immigrants. As Dr. Wm. J. Mayo truly said in an address at the Boston City Hospital, November 14, 1923, before the new act was passed:

> The alien is a public health problem, just as he is a social problem, and the public hospital sees the dark side of this picture. In the American of several generations, the doctrine of moral obligation has become thoroughly ingrained. In southern Europe the Oriental point of view more or less prevails that no obligation which is not enforcible exists. The laxity of the conduct of the law in the United States, the slowness of justice, and the extraordinary latitude allowed the offender against the community, give the criminal more than a sporting chance to escape punishment and have exposed the administrators of law to the contempt of the class of offenders brought to us in recent years by immigration. And these are the people with whom our public hospitals are overcrowded. Our courts have been filled with alien lawbreakers until the people have arisen in righteous indignation and reduced the number of immigrants to 3 per cent. of the number already here from each country. If the percentage system of immigration in effect in 1890 could be reverted to, as has been advised, a much more desirable class of citizens would be brought from the countries that gave birth to the United States and its concept of government.

The new Immigration Act will not only bring us (1) a limited, more homogeneous and more easily assimilated immigration, but (2) an immigration of generally higher intelligence than has characterized the bulk of the people who have come here in recent years and (3) greatly reduced numbers of aliens belonging to many of the "socially inadequate" classes. The original argument in favor of a percentage limitation was economic. The fundamental reason for its continuance is biological.

The act of 1924 contains a new provision—that of immigration visas—so important that if it contained nothing else the time and the labor involved in its preparation and discussion would have been well spent. For many years students of immigration have advocated some sort of preliminary inspection of intending immigrants overseas, before they start on their journey, as a necessary and a humane measure—a benefit to the United States and a means of preventing unnecessary hardship to the alien. The new law embodies the first practical attempt which the United States has ever made to conduct a preliminary selection abroad with a view to weed-

ing out at least some of those who are debarred by our present laws. Complete overseas inspection, general and medical, is impossible owing to the limited jurisdiction of our consular service under the existing treaties, and because foreign governments have objected to our taking such a step. But foreign governments can hardly object to the requirement in the new law of having the intending immigrant fill out a questionnaire before an American consul, showing whether or not, according to his own statements, he is qualified for admission to the United States under our laws.

The essentials in the new plan are as follows: Aliens entering the United States must have passports from their home government, viséed by an American consul. Hitherto the visa could be withheld only if the alien was known or thought to hold views inimical to organized government. Consular officers could exercise no discretion in the matter of giving visas to prospective immigrants, even when it was certain that the aliens would not be admitted or, if admitted, would be most undesirable additions to our population Under the new law, a consular officer abroad has a real discretionary power of selection, for he may refuse to issue an immigration visa "if he knows or has reason to believe that the immigrant is inadmissible to the United States under the immigration laws" The consul's action is final Every immigrant must bring with him his passport and its accompanying visa Before securing the visa, the alien must answer a very full questionnaire, essentially the same as that which he is asked on his arrival here, intended to show whether he is eligible for admission under our laws. This document includes the question whether the alien or either of his parents has ever been in an institution or hospital for the care and treatment of the insane, must also be accompanied by the alien's *dossier* and prison and military record, and must be sworn to before the consul.

While there will undoubtedly be many cases of perjury and of fraud in this connection, there can be no question that a very great many undesirable aliens, excludable by law, will be headed off by our consuls when application is made. This plan will reduce hardships to the absolute minimum; avoid the division of families; save the nationals of other countries the expense, perils and hardships of the ocean trip to the United States only to find that for some reason the immigrant or some member of his family can not enter. Certificates are to be issued only up to the numbers allowed by the quotas, and are good for four months, so that if an alien comes at any time within that period he will not be denied admission as being in excess of the quota allowance. This provision also stops the rush of aliens at the beginning of each month, and makes pos-

sible a more deliberate and more thorough medical inspection—an improvement very greatly to be desired. The real inspection, medical and otherwise, will be made at our own ports, as it should be, but many of the aliens who would be excluded on examination here will never start on their journey. The certificate plan, then, will, through the preliminary selection overseas, benefit the United States. It will also very greatly diminish the hardships of the alien It is selective. And it is humane

Three other clauses in the Act of 1924 deserve mention because of their eugenic importance: (1) The fines on the transportation companies for bringing inadmissible aliens are very considerably increased and this will greatly help in the enforcement of the law; (2) any alien who at any time after entering the United States is found to have been at the time of entry not entitled to enter or to have remained here for a longer time than permitted shall be deported; (3) alien seamen must be detained on board ship until they have submitted to inspection, including a medical examination. With certain exceptions, alien seamen found excludable are prohibited from landing.

The new law is a long step forward along eugenic lines, and as such deserves hearty support on the part of all who desire that the immigrants who come to us shall be physically, mentally and morally sound and desirable progenitors of future Americans. Various suggestions put forward from time to time by close students of immigration problems who are especially concerned about the eugenical selection of our immigrants have, however, not yet become part of our immigration policy. These deserve careful consideration at this time.

I. Cash Bonds

Reference has already been made to the provision in the act of 1917 which permits the secretary of labor to admit certain classes of aliens under bonds, and to the evils which have resulted from the abuse of this bonding privilege.

The way the bonding provision actually works out is this. The bonds are usually in amounts between $500 and $1,000. They are taken out through a surety company by a relative or friend of the alien, or by some immigrant aid society. For many reasons, in most of which the relative or friend plays the chief part, the alien admitted on appeal has too often been "lost." Change of residence, change of name, and removal to another state have been common schemes for bringing this about. In many cases the relatives or friends have been willing enough to care for the admitted alien for a time, but soon lost interest, and were quite ready to have their

bonded fellow-countryman taken care of by the community. The bonds are for too small amounts. They can not always be enforced. They have too often become mere "scraps of paper." A large percentage of all bonded aliens have in the past violated and forfeited their bonds and are now here, some in public institutions; some supported more or less of the time by public or private charity, and most of them at large in the community, a social menace because, themselves in many cases mentally defective, they have been producing mentally inferior children. The "paper" bonding system has worked incalculable injury to our population.

This situation, recognized as such by competent and unprejudiced authorities on immigration, should be remedied. (1) Aliens belonging to the "mandatorily excludable" classes should never be admitted on appeal over the heads of the medical examiners, as has been urged earlier in the present article And (2) in all other cases when aliens are admitted on appeal *cash* bonds in substantial sums *should be required*

Section 21 of the Act of 1917, which provides for bonding, expressly states that in lieu of other ("paper") bond, any alien "may deposit in cash with the secretary of labor such amounts as the secretary of labor may require, which amount shall be deposited by said secretary in the United States Postal Savings Bank." If the alien became a public charge, the money would be directly available towards the expenses of his support; and no suit to recover would be necessary. As things stand now, the expense of suing, on the part of any state or municipality or town, is usually too great to make it worth while to institute proceedings for the recovery of the money, the amount of which is usually far too small. A $1,000 bond should be the minimum, and $5,000 would not be too much in many cases.

In connection with cash bonds several points should be kept in mind. Congress has already approved them as an alternative to paper bonds. A cash bond is a perfectly fair requirement in the case of any alien who is given the special privilege of being admitted contrary to law, for the United States is taking a decided risk in admitting him. If, at the end of say five years, the alien appeared and gave proof that he had not become a public charge, the capital sum of the deposit, plus interest, should be returned to him. In case he did not appear, the United States could use the money for hunting him up, and for deporting him if found. As things stand under our present bonding system, the government too often does not attempt to find an alien who has forfeited his bond because of the expense involved and the difficulty or impossibility of locating him. If a cash deposit of a considerable amount were

required, the relatives and friends of the alien and the immigrant aid societies would be much less ready than they now are to appeal the cases of excluded aliens. If the alien himself had to put up the cash bond it would be reasonable evidence that he would not become a public charge. Cash bonds, as here urged, would force the steamship companies to be more careful in permitting the embarkation of aliens who would probably be excluded on arrival here, because far fewer such would be allowed to enter on appeal. Another most desirable result of such bonds would be the very great decrease in the harassing and laborious work of hearing appeal cases in the office of the secretary of labor, and would thus also largely do away with the present conditions of political pressure for the admission of aliens on appeal. Finally, cash bonds would, without any doubt whatever, result in the landing of a very greatly reduced number of undesirable aliens.

Cash bonds, of considerable amounts, were recommended by the Sub-Committee on Immigration of the Eugenics Committee of the United States of America in its first report (January, 1924).

II. Medical Inspection to be made during the Voyage

The impossibility of conducting thorough medical examinations during the hurried inspection at the port of arrival has led to a demand that such examination should be carried on during the voyage, when there would be ample time for the work, and when the aliens could be observed for several days in succession. Definite action looking towards this end was taken at a conference of alienists and social workers held in New York City, November 16, 1912, at which the most important scientific bodies in the United States then dealing with the treatment and prevention of insanity were represented.[5]

This conference unanimously endorsed the adoption of "a provision authorizing the detail of commissioned medical officers of the U. S. Public Health Service to any vessels bringing immigrants to the United States, such medical officers being required to examine immigrants, with special reference to their mental condition, on the voyage to this country." This suggestion was later embodied in a section of the Act of 1917, authorizing the secretary of labor to enter into negotiations with the transportation companies with this end in view. So far as the present writer is aware, no action on

[5] American Medico-Psychological Association, National Committee for Mental Hygiene, New York Psychiatrical Society, New York State Charities Aid Association, Committee of One Hundred on National Health, New York State Hospital Commission, Immigration Committee of the Eugenics Section of the American Breeders Association.

this matter has ever been taken by our government. The National Republican Club (New York) later passed a resolution to the following effect: "In so far as existing law may be inadequate to permit the placing of inspectors and physicians on vessels bringing aliens to this country, it should be amended." This suggestion, it should be observed, applies to placing American medical officers on the steamships, and would therefore remove the responsibility from the transportation companies, where it would seem properly to belong.

Dr. Spencer L. Dawes, medical examiner of the New York State Hospital Commission, has for some years been a very able advocate of a plan which has been widely and enthusiastically endorsed[6] Dr. Dawes's proposal is that as a prerequisite to the granting of a visa by an American consul the emigrant shall present a medical certificate (on a blank provided by the Immigration Service) embodying family and personal history, and certifying that the emigrant is not of the excluded classes. This certificate is to be based on a thorough medical examination made by a physician employed by the transportation company which is intending to bring the alien to the United States. Fines are to be provided, as at present, in all cases in which ineligible aliens are brought here The reasons for such a provision are the necessarily hurried, inadequate medical examinations by our own officials at the port of landing; the impossibility, owing to the attitude of certain foreign governments, of having a medical examination overseas by United States officials, and the very discouraging situation here of seeing thousands of mentally and physically unsound aliens landed, either (1) because the hurried medical examination here can not detect the disabilities or (2) because of the landing of such undesirable aliens on bonds. Dr. Dawes's plan places the responsibility directly where it belongs. If the steamship company carries out the physical examination it can not complain if it should be found, on the immigrant's arrival in the United States, that any passenger is, from a medical standpoint, ineligible under the provisions of the statute. On the other hand, if medical examinations were carried out by officers of the United States at the European ports it would be impossible to shift the responsibility to the steamship company for deportation of an ineligible immigrant by reason of physical or mental disability.

A very important part of the Dawes proposal is the inquiry into the personal and family history of the emigrant, which should be minute and thorough.

[6] By the Interstate Conference on Immigration, the New York State Federation of Women's Clubs, the National Republican Club, the U. S. Chamber of Commerce, the American Mining Congress, numerous district branches of the New York League of Women Voters, etc.

If the steamship company is held responsible for the verification of this phase of the applicant's examination, all the hardship cases would be absolutely eliminated. What happens now is that an immigrant voluntarily separates himself from his family, which may be composed of one or more children mentally deficient, and then, when the alien has made enough money to import his family a howl goes up as to the separation of these unfortunates. Unquestionably here is true hardship, but it must be borne in mind that the original separation was the voluntary act of the people who desired to enter the United States.

The plan is simple, feasible and would be highly effective. Canada, which is well in advance of us in the matter of selecting her immigrants, requires a medical examination by the steamship companies' doctors, and aliens found mentally or physically inadmissible after arrival at Canadian ports must be returned at the expense of these companies.

III. Higher Physical Standards

Close students of the eugenical aspects of immigration have for many years felt that too large a proportion of incoming aliens have been of low vitality and poor physique—distinctly undesirable members of our population yet not specifically excludable under existing statutes. The matter has more than once been brought to the attention of Congress, but without result. This whole matter was carefully considered by the Sub-Committee on Immigration of the Committee on National Affairs of the National Republican Club of New York, under the able chairmanship of Mr. William Williams, and the following resolution was unanimously adopted at a meeting of the club held February 17, 1920:

The general physical requirements for males coming here to perform manual labor should be raised moderately and made somewhat more definite than they now are. While we are not in accord with those who would make these requirements as severe as those governing admission to the Army and Navy, yet we believe that by analogy certain reasonable minimum physical standards should be adopted, either by Congress or by the U. S. Public Health Service under authority of Congress, and applied to male aliens of the class referred to. After observing for a time their operation, the experience gained would show whether it was desirable also to adopt analogous physical standards in reference to other classes. Too many immigrants of indifferent general physique have in recent years been finding their way into the United States. With such standards to serve as a guide, there would be less excuse than there now is for the steamship companies to bring here laborers who, while not suffering from any loathsome or dangerous contagious disease, are nevertheless persons of poor physique or impaired general health.

This would seem to be a reasonable and logical, as it also is a most desirable, step for us to take in this matter.

IV. Mental Tests

In this very able address in Boston, November 14, 1923, already referred to, Dr William J. Mayo spoke as follows:

> Eugenics as applied to man is still in its infancy During the World War, tests showed that 18 per cent. of the young men drafted were not developed beyond the mental age of eleven years Since our form of government must always be controlled by men of average intelligence, the general average of intelligence must be raised if the standards of government are to be raised. This 18 per cent. of citizens in the Boy Scout stage of development, mentally too low to be reached by reason, easily led by an appeal to prejudice, and voting solidly, are within 3 per cent of controlling the average election. Our great safeguard, general education, will not aid them or us. Nature has fixed their mental status This substratum of society presents one of the greatest problems of American citizenship. It will exist long after a proper settling of the immigration question, and will tax the best minds of the future to remedy.

The grave dangers that thus threaten our future race and our institutions have led eugenicists to the conviction that only aliens who attain a certain standard of intelligence should be admitted to this country.

The Sub-Committee on Immigration of the Eugenics Committee of the United States of America, in its first report, made the following brief but inclusive recommendation:

> No alien should be admitted who has not an intellectual capacity superior to the American average. Aliens should be required to attain a passing score of, say, the median in the Alpha test, or the corresponding equivalent score in other approved tests, these tests to be given in the native tongue of the immigrant. Further, if possible, aliens whose family history indicates that they come of unsound stock should be debarred.

The American median here referred to, which is now fairly well known from the Army tests, can be readily worked out for use in new tests to be applied to aliens.

Experts have estimated that had mental tests been in operation and had the "inferior" and "very inferior" immigrants been refused admission to the United States, over 6,000,000 aliens now living in this country, most of them potential fathers and mothers of future Americans, would never have been admitted. It surely is high time for the American people to put a stop to such a degradation of American citizenship and such a wrecking of the future American race.

That mental tests as here recommended would certainly operate to debar large numbers of aliens who are of inferior intelligence is perfectly certain. On the other hand, it is no less clear that the

public as a whole is not yet educated up to an acceptance of such tests as a logical part of our immigration policy.

V. Registration of Aliens

With the increasing restrictions which have been put upon immigration, the smuggling and surreptitious entry of aliens across the Canadian and Mexican borders and by sea have naturally enormously increased. It has been estimated that probably 100 aliens daily enter this country in violation of our laws, and the number may be very much larger. While many of these "bootleg" immigrants are probably mentally and physically up to the very low standards which we have set, the majority doubtless belong to the diseased and defective classes who should most rigidly be excluded. The new Border Patrol, made possible by an appropriation of $1,200,000 for the current year, will help to remedy this very bad situation. But more is needed. Secretary of Labor James J. Davis strongly advocates a plan for registration as an effective way of outwitting the border-jumper and the smuggled alien. Under this plan every alien would be required to register or enroll annually. Failure to register would be punishable by fine. Registration would be carried out by the naturalization service of the Department of Labor and perhaps also by interested individuals and organizations. A final check-up of aliens who failed to comply with the law would occur when an alien applied for his citizenship papers. This plan would not only help in the work of assimilation and education, but, what is of even more importance, would reveal the presence of aliens who had entered the country in violation of the law, in whose cases there would be no record of legitimate admission by immigration inspectors.

Summary

In conclusion, the various methods which have here been discussed for raising the mental and physical standards of our immigrants may be briefly summarized. (1) Our immigration laws should be rigidly enforced all along the line. (2) "Mandatorily excludable" aliens should never be admitted. (3) All border-line cases, which are mostly those liable to become public charges for medical reasons, should be debarred unless there is *very strong* evidence in favor of admission. (4) Appeals from adverse decisions of the boards of special inquiry should rarely be sustained. (5) There should be no yielding to political pressure in the case of any alien who belongs to any of the excluded classes. (6) When, in very rare cases, aliens are admitted under bond, the bonds should

be cash bonds, in considerable amounts. (7) As a prerequisite to the granting of an "immigration visa" by an American consul, the alien should present a medical certificate from a physician employed by the steamship company to the effect that such alien is not of the excluded classes. If diseased or mentally or physically defective aliens are found by our examining medical officers, the steamship companies should be fined, and the alien deported. (8) Higher physical standards should be required. (9) No alien should be admitted who has not an intellectual capacity superior to the American average. (10) All aliens should be required to register annually.

THE MANAGEMENT OF FOREST PROPERTIES IN THE CALIFORNIA PINE REGION AS A PROBLEM IN APPLIED ECOLOGY[1]

By S. B. SHOW

U. S. FOREST SERVICE

THE most important and difficult task of the practicing forester in the Forest Service is that of handling the cutting of the mature forest so that a new forest may follow promptly.

I have pointed out elsewhere the profound influence that fires have exerted on the virgin forest. The various stages in the process of forest destruction may more or less arbitrarily be summarized as: (1) The relatively fully stocked forest, utilizing well the available space and food, but slightly affected by fire, showing a low percentage of fire-scarred trees; (2) the half-stocked forest, the mature trees badly scarred, distribution patchy, with underbrush and young trees struggling for the space released by death of veterans; (3) the very open and decadent remnants of the forest, with brush in the ascendency; (4) the brushfield.

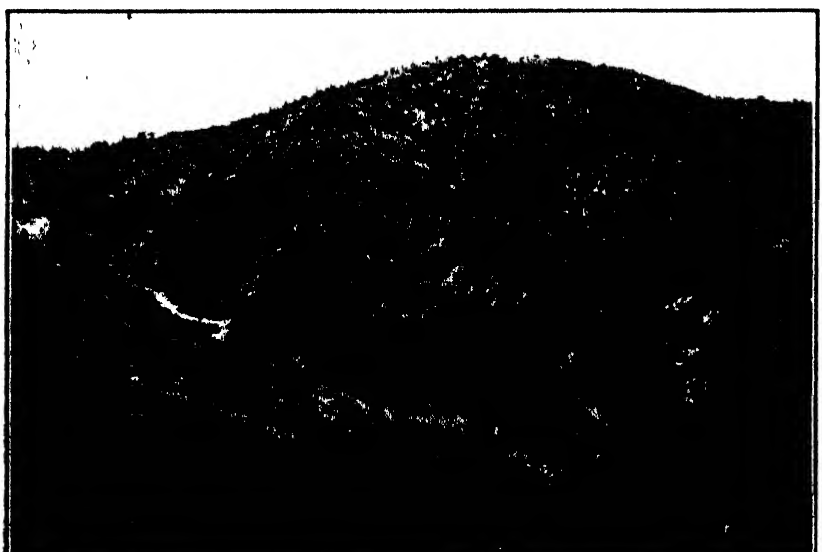
One of the important influences of repeated fires, acting through the creation of fire scars, has been to make possible the attack of wounded trees by wood-destroying fungi. Thus, at all stages in the combat between forest and fire, the forest trees, varying with species, are affected by fungi.

Fire, aside from reducing the virgin forest, has a selective action in stands composed of more than a single species. The yellow and sugar pine are decidedly more resistant to fire than are Douglas and white firs and incense cedar. Thus the virgin forest of to-day, after centuries of recurring fires, displays a higher proportion of the pines than if normal and uninterrupted succession had been operative, for the firs and cedars are markedly more tolerant than the pines and thus must inevitably tend to dominate mixed stands, assuming no disturbing element such as fires.

It is thus impossible to assume that the composition of an existing mixed forest furnishes a reliable criterion of what that forest may become, once fires are stopped. How radically the composition may change is indicated by data covering 250,000 acres in Lassen County. On the basis of the composition of mature forest, 80 per

[1] Given at joint meeting of Ecological Society and Society of American Foresters, American Association for the Advancement of Science, Stanford University, June 27, 1924.

Repeated fires in the virgin pine forests of California are responsible for a marked change in the composition and character of the forest. Trees, if not killed, are fire scarred at their base and weakened so that later they become an easy prey to beetles and to wind. In the openings, where groups of trees have been killed out, a dense brush growth comes in and each succeeding fire is more intense and more destructive than the preceding. In this brush, seedlings have a hard struggle for existence.



The final results of repeated fires is the brushfield. Repeated fires kill off all seed trees and prevent the reproduction from becoming established. With repeated fires there is a deterioration of the site through the loss of humus and the finer soil particles, washed away when the soil is exposed. Even with protection for many years, nature can not reclaim the area.

cent. is classed as yellow pine type, with a small admixture of white fir. Considering the advance reproduction which will form the basis of the new stand, only 51 per cent. can be classed as yellow pine type or 64 per cent. of the area, as judged by the mature timber.

Still considering only the physical facts of the situation, it is to be noted that studies over a period of twelve years show clearly that the advance reproduction is by far the safest and most certain means of continuing the forest. Reproduction after cutting is generally difficult and uncertain to secure and where advance reproduction is present, it should be saved.

The advance reproduction, starting under the virgin forest, naturally has a higher percentage of the tolerant climax species than of the intolerant pines, the persistence and dominance of which is largely due to fire.

One further important consideration is the vastly greater amount of defect due to fungi in the tolerant firs than in the intolerant pines.

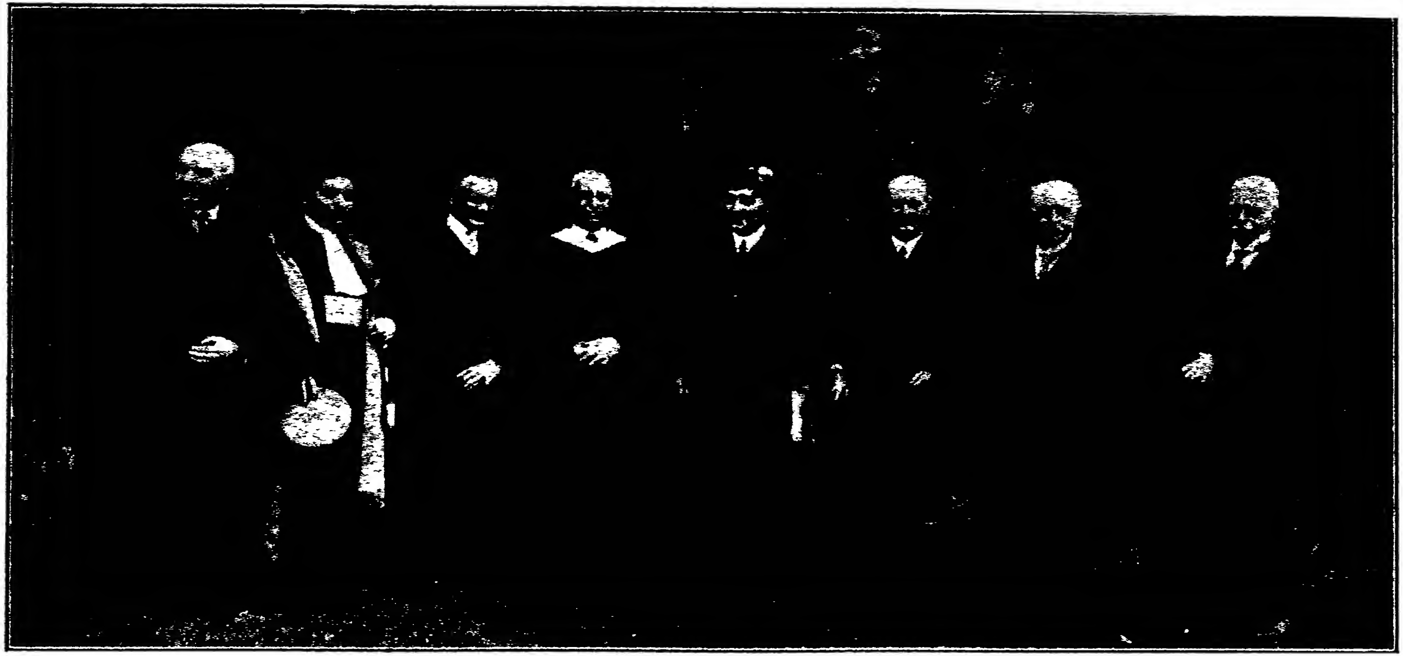
Turning to the economic factors that affect the management of national forest timber, we find that the wood of the firs and cedar is very much less prized than that of the pines The difference is so great that only with difficulty is it possible to secure cutting of the firs to as great a degree as is desirable for the health and productiveness of the new forest. Greater defect of the firs accounts for a large part of the difference in esteem between these species and the pines, but inherent qualities of wood also tend to throw values in the same direction Because of this, it is very desirable to maintain the pines as important constituents of the new forest, though this does not necessarily mean any attempt to eliminate the firs and cedar.

The problem in a nutshell thus is to control in some degree the progress toward domination of the tolerant and relatively nonvaluable firs, without the deliberate sacrifice of the advance reproduction in which the firs predominate.

In countries with a more intensive silvicultural management than our own, composition is controlled in mixed stands by artificial regeneration or by adjustment of time and methods of cutting to meet the seed production and conditions for establishment of the particular species it is sought to favor. With the very crude silviculture now possible in the western United States, neither planting nor flexibility in locating cutting areas can be systematically employed. The most that can be done is to create the best possible conditions for the establishment of the pines and to leave abundant seed trees.

While the firs and cedar easily outstrip the pines in establishment of reproduction under the virgin forest, it is apparently the reverse under the altered conditions resulting from heavy cutting of the virgin forest. I say apparently with deliberation, for our investigations are not at all decisive on this point. Not only is reproduction after cutting generally slow, but the amount of attention given the subject has been seriously inadequate. It is clear that a moderate cutting, removing say two thirds of the merchantable volume, does not always go far enough to distinctly favor the pines, even when every effort is made to cut the firs heavily and the pines lightly. Yet for flexibility in managing forests, it is often desirable to practice just such a type of cutting.

Thus, in order to attain the desired objective of full utilization of the land with forests containing the pines as well as the firs, it is necessary not only to recognize the basic facts—the inevitable tendency toward the climax forest of fir—but to utilize in full the act of cutting as the only tool available to arrest the progress of normal succession.



SCIENTIFIC MEN AT THE CENTENARY OF THE FRANKLIN INSTITUTE

At the celebration of the hundredth anniversary of the Franklin Institute in Philadelphia, a convocation was held at the University of Pennsylvania, and the honorary degree of doctor of science was conferred on the distinguished scientific men shown in the photograph. From left to right are: Dr. Edwin Wilbur Rice, Jr., honorary chairman of the General Electric Company; Professor Charles Fabry, of the University of Paris; Dr. William C. L. Eglin, president of the Franklin Institute; Dr. J. Hartley Merrick, vice-provost of the University of Pennsylvania; Dr. Jo[illegible] H. Penniman, provost and pres[illegible] of the University of P[illegible]; Sir William Henry Bragg, the Royal Institution; Sir Charl[illegible] Algernon Parsons, the British [illegible] and Professor P[illegible] [illegible]he University o[illegible]

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

THE SPEED OF LIGHT

LIGHT is the swiftest thing in the world, speaking either practically or theoretically. Practically, because we do not know of anything faster. Theoretically, because we can not conceive of anything faster. For, according to Einstein, a body gains in mass as it gains in speed. To push the smallest particle faster than light would require an infinite force and infinite forces do not exist outside of books.

The velocity of light through empty space seems to be one of the inexorable limitations of nature like absolute zero. It is a constant quantity that turns up in all sorts of calculations. It is not only the speed of the visible rays of light, but also of the X-rays that are some ten thousand times shorter and of the radio rays that are more than a million million times longer. The flash of a firefly and the rays of the sun travel at this same velocity. It is the yard stick by which the starry heavens are measured, and molecular magnitudes as well. It gives us a fixed standard for time. Consequently it is important that its value should be known as exactly as possible.

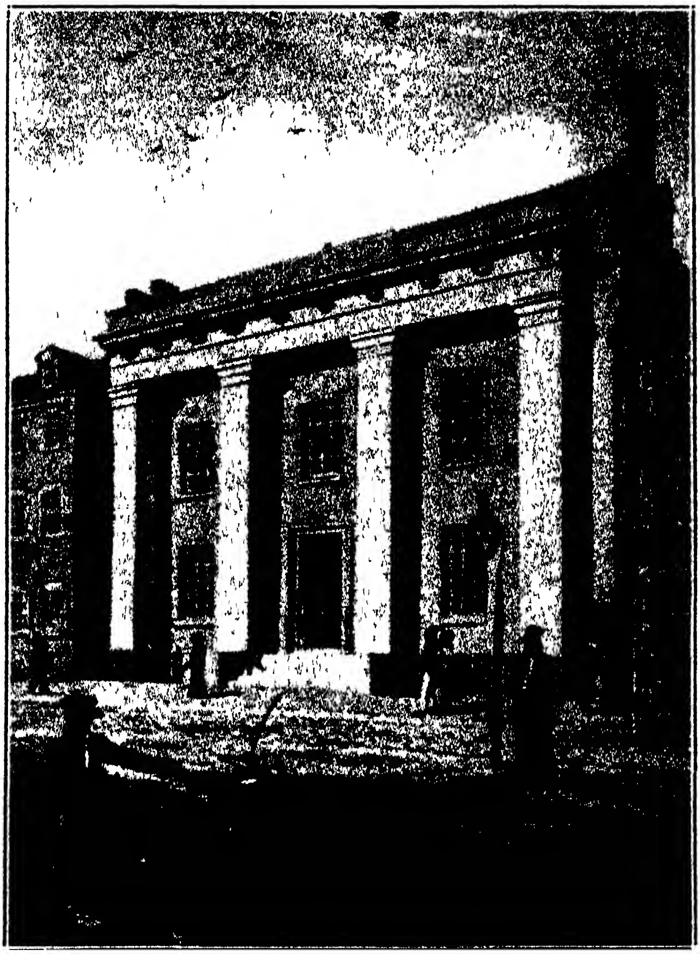
But the reason given by Professor A. A. Michelson, of the University of Chicago, for undertaking a new determination of this constant was different from any of these. When asked by a member of the U. S. Coast and Geodetic Survey why he was going to put in the summer repeating the experiments, since previous observers had already got remarkably close figures, he answered, "Because it is such good fun."

Then, seeing that this reply did not satisfy the interlocutor, he added another and more practical reason, that if the velocity of light is known to one part in 200,000, it would be possible to set up a flash light on one peak and a mirror on another as far away as could be seen, and so get the distance between them in two weeks as accurately as it can now be measured by the chain in two years. This method would also be of use in determining distances where direct measurements are impossible.

Timing the speed of light has been a hobby of Professor Michelson from boyhood. When he was a midshipman at Annapolis, he set up a new form of apparatus with a range of 2,000 feet along the sea wall of the Naval Academy, and got better results than had been obtained before. Later he assisted Professor Simon Newcomb in a series of determinations.

In 1923 he took up the work again in California on a longer range and with more delicate apparatus than ever, but the forest fires made the air too hazy. But last summer he succeeded in getting excellent determinations which he has reported at the centenary celebration of the Franklin Institute.

The method used is so simple that any one can understand it, although the difficulty of carrying out a determination with such unapproached precision can hardly be appreciated. It consisted essentially in sending



THE FRANKLIN INSTITUTE

The building erected at Philadelphia in 1825 is occupied to-day by the Institute and houses one of the largest and most important technical libraries. From a print in the book issued to commemorate the centenary of the institute.

a beam of light from one mountain peak to another at known distance, reflecting it back from a mirror there, and timing the round trip. The sending station was located on Mount Wilson, not far from the hundred-inch telescope, the largest in the world. The receiving and reflecting station was on the top of Mount San Antonio, 22 miles away. The distance was measured by the U. S. Coast and Geodetic Survey with an accuracy of two parts in a million.

The source of the ray was a powerful electric arc lamp giving a light almost as bright as the sun. Passing through a minute hole in front of the lamp the ray was caught on a revolving octagonal mirror, sent to Mount San Antonio, reflected back from there and received on the original mirror which is revolved at such a rate as to catch the returned ray on the succeeding face of the octagon. The mirror was rotated by a blast of air playing on a little windmill, and made 530 revolutions a second, its speed being regulated by a tuning fork of known pitch. The making of the mirror was one of the most delicate parts of the apparatus for if the angles of the octagon were not exact, the results would be erroneous. When this was completed and its angles tested, they were found to be equal with an uncertainty of only one part in a million.

In this simplified apparatus only two measurements are necessary: (1) the distance between the two stations which is known by direct measurements, and, (2) the time of the round trip, which is given by the speed of the rotation of the mirror. The average results of eight observations gives the velocity of light in a vacuum as 186,300 miles per second. This can not be wrong by more than twenty miles.

But Professor Michelson is not yet satisfied. He will try it again next summer and hopes to get it right within a mile by steadying the speed of the mirror. He thinks it possible that the distance may be extended to a hundred miles which would enable him to get the figure accurate to within one part of a million.

Let's hope, for other reasons as well, that there will be no forest fires in California next year.

THE MELTING POT

How long does it take a racial melting pot to melt? We are, as the newspapers word it, "making new Americans" at the rate of five thousand a day, if we take the highest record of the New York Naturalization Bureau; fifteen new citizens for every minute that the court was in session.

Never before in the history of the world has such a fusion furnace been run at such high speed or on so large a scale or with such diverse ingredients as our modern American amalgamation process. How long will it take for the mixture to form a homogeneous mass, without blowholes or segregated crystals to weaken the metal?

Seven or eight hundred years. That at least is the most definite estimate I have been able to find. It comes from Flinders Petrie, Egyptologist of the University of London. In his remarkable book, "The Revolution of Civilization," he traces the rise and fall of eight successive culture periods, and finds that their average duration is between 1,300 and 1,500 years, "from shirtsleeves to shirtsleeves," to put it in American parlance, though perhaps we should say "from bare arms to bare arms."

THE PITTSBURGH BUILDING OF THE RENSSELAER POLYTECHNIC INSTITUTE

Housing the library and the administration offices

THE BROADWAY APPROACH TO THE RENSSELAER POLYTECHNIC INSTITUTE

At the top of the steps was unveiled a tablet on the occasion of the celebration of the centenary of the Rensselaer Polytechnic Institute commemorating this event and the founder of the institute, Stephen Van Rensselaer. The centenary was celebrated on October 3 and 4, with representatives in attendance from universities and engineering societies from the United States and abroad. In the issue of THE SCIENTIFIC MONTHLY for October, 1924, will be found an article on "The Rensselaer Polytechnic Institute and the Beginnings of Science in the United States," by Professor Ray Palmer Baker.

Once a people has sunk into senility, it can only be regenerated, according to Professor Petrie, by the infusion of new blood, that is, by admixture of race. For complete assimilation of the foreign element some seven or eight centuries are necessary. Then the nation is at the height of its energy and ability, and may maintain its superior civilization for four or five centuries before it begins to collapse and finally to relapse into barbarism.

Such may be the lesson of history, and it may serve to allay our American impatience and teach us to realize that it is likely to be a long time and may be a hot time before our ideal 100 per cent. American appears. But we may question whether such deductions from the past are applicable to the unprecedented conditions of the present. Two new and fundamental factors have recently entered into the problem, the deliberate restriction of both kinds of "immigration"—the foreign-born and the native-born additions to our population.

Dr. Harry H. Laughlin, of the Eugenics Record Office of the Carnegie Institution, said at the recent Toronto meeting of the British Association for the Advancement of Science that "the greatest turning point in human history was reached when mankind conceived the idea of consciously controlling his own evolution. If this principle is to be put into effect, then control of immigration is one of the major factors in human evolution, and the element most easily managed by national law and international agreement."

According to Dr. Laughlin's investigations, only 11.3 per cent. of the 13,920,692 foreign-born men in the United States in 1920 were making any addition to the native intelligence of the American people. Slightly more than 26 per cent. were of average intelligence, while 62 per cent., or close to 8,000,000 men, were below the average. He therefore concludes that "the immigrants of the last generation have not improved the average quality of the American people."

A still more pessimistic view was expressed at the Toronto session by Professor William McDougall, psychologist of Oxford and Harvard. "As I watch the American people speeding daily, with invincible optimism, down the path that leads to destruction, I seem to be watching one of the greatest tragedies of history," he said, and again, "I fear that when a few hundred years hence, the list is made up of the great nations whose decline is due to the deterioration of the race which composed them, England will have to be added to such nations of the past as Greece, Rome, Persia, Egypt and Spain."

Professor McDougall thought three measures would be necessary if the racial stock is to be kept from decline. First, knowledge of birth control should be disseminated by clinics to all classes. Second, immigration should be selective, which the United States is beginning to try. Third, men of proved ability, such as engineers, skilled workmen and college professors, should be paid in proportion to the number of their children. This plan was adopted for privates in the British army during the war and has been applied to the fellows of the National Research Council of the United States, and is being considered in France.

There is some disagreement among geneticists as to the extent of the damage being done to our racial stock by present dysgenic tendencies and more disagreement as to the eugenic measures best to counteract them, but all agree that quality and not quantity is now the important problem in

BUST OF PASTEUR

Recently unveiled at the American Institute of Baking in Chicago by Professor S. P. L. Sorensen, director of the Carlsberg Laboratories in Copenhagen, left, and Dr. Max Henius, president of the Wahl-Henius Institute.

population. G. Udny Yule* of Cambridge, using the mathematical formula of Verhulst, of Belgium, arrives at almost the same figure for the natural limit of the population of the United States that Professor Raymond Pearl, of Johns Hopkins, reached independently, namely, about 199,000,000. According to this our country is already more than half filled up and the danger is lest it should fill up too fast and with the wrong sort of folks. No nation ever started out in life with a larger and better assortment of chromosomes, but we should see to it somehow that the best of them do not get lost in the shuffle.

THE SENILITY OF CIVILIZATION

DAY by day the newspapers report the excavation of the buried city of Magna Leptis in Tripoli, as last year they told us of the excavation of the buried tomb of Tut-Ankh-Amen in Egypt. We receive from these researches the same shock of surprise at the realization there were people so long ago who accumulated wealth and spent it in the pursuit of pleasure even as we do, who cultivated art and learning, and believed, like us, that they had reached the pinnacle of human attainment, and yet that their proud achievements had been so drifted over by the sand of time that their very existence had been forgotten. The resurrection of such entombed civilizations serves for us the same purpose as the ancient Egyptian custom of passing around an image of a mummy at a feast, a memento mori, a reminder that civilizations like men are mortal, and that, if we may judge the future by the past, our own will perish too and be forgotten.

Helmolt in his history of the world observes that "It is remarkable that even to the present day every philosopher, who has compared the processes of man's development to the several periods in the life of the individual, has believed his own time to be the age of senility." It has seemed to each successive generation, as it did to Bernard of Cluny in the twelfth century, that "The world is very evil, the times are waxing late." In every previous century, as in ours, there have been those who have expected the world to come to an end within the lifetime of men then living. Humanity has persistently maintained a *fin de siècle* attitude, regardless of the calendar.

> There is the moral of all human tales,
> 'Tis but the same rehearsal of the past.
> First freedom and then glory—when that fails,
> Wealth, vice, corruption, barbarism at last,
> And history with all her volumes vast
> Hath but one page.

But while all the physicians, who feel themselves called to consider the health of humanity, agree that the patient is in a very dangerous state and likely to pass away at any time, they fail to agree on the diagnosis of the disease leading to the fatal termination. According to some, it is too much selfishness; according to others, it is excessive altruism. Some call the malignant microbe democracy; others call it plutocracy. Some see the danger in nationalism; others in internationalism. The leading prophet of the latter school is Oswald Spengler, who has recently brought into action a 42-centimeter gun in the form of two profound volumes on "The Downfall of Western Europe." His position is shown by the following quotation: "A nation is humanity in living form. The practical result of theories of world-betterment is, without exception, a formless and there-

fore unhistorical mass. All cosmopolitans and enthusiasts for world-betterment represent fellaheen-ideals, whether they know it or not. Their success means the abdication of the nation within the historical sphere, to the advantage, not of world-peace, but of other nations."

Professor J. W. Gregory, of the Glasgow University, thinks, like Lothrop Stoddard, that the progress of European civilization has been checked by the rising tide of color. At the recent Toronto meeting of the British Association for the Advancement of Science, he said: "During the past half-century the unprecedented increase in the white race has been exceeded by that of the colored people. Increased disparity in numbers means, in a democratic age, an inevitable transfer of power, while the former prestige of the white man has been undermined by his own beneficent rule. Alike in war and peace the personal authority which the white man held in 1900 has undergone a momentous decline. White colonists have no chance of permanently occupying land near the over-crowded parts of Asia or accessible to the fast multiplying Negroes of Africa. White merchants may find in these regions profitable trading centers and may for a time rule and administer them; but when white enterprise has subdued the land, built railways and utilized the rivers, the colored man will oust the white from all but the few posts that require experts."

A. J. Hubbard in "The Fate of Empires" considers it a problem of reconciling the interests of the transitory individual with those of the continuing race. He puts his point in a neat analogy: "Life is an entailed estate. It is to the interest of the life tenant to break the entail." The conflict can not be reconciled by reason, so he concludes that "A true and stable civilization can never be more than a by-product of religion."

Certain psychologists are now working up a series of intelligence tests to measure the gradual onset of senility as the school tests measure the development of maturity of mind. It is time that the social psychologists worked out a system of diagnosis applicable to nations so that the development of fatal maladies could be discovered at incipiency, and, if possible, averted.

THE SCIENTIFIC MONTHLY

DECEMBER, 1924

THE CENTENARY OF THE FRANKLIN INSTITUTE[1]

THE NATURAL AND ARTIFICIAL DISINTEGRATION OF THE ELEMENTS

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It is not my intention in this paper to give a detailed account of the natural disintegration of the radio elements or of the methods employed to effect the artificial disintegration of certain light elements. I shall assume that you all have a general knowledge of the results of these investigations, but I shall confine myself to a consideration of the bearing of these results on our knowledge of the structure of the nuclei of atoms.

There is now a general agreement that the atoms of all elements have a similar electrical structure consisting of a central positively charged nucleus surrounded at a distance by the appropriate number of electrons. From a study of the scattering α particles by the atoms of matter and from the classical researches of Moseley on X-ray spectra, we know that the resultant positive charge on the nucleus of any atom, in terms of the fundamental unit of electronic charge, is given numerically by the atomic or ordinal number of the element, due allowance being made for missing elements. We know that with few exceptions all nuclear charges from 1 for the lightest atom hydrogen to 92 for the heaviest element uranium are represented by elements found in the earth. The nuclear charge of an element controls the number and distribution of the external electrons, so that the properties of an atom are defined by a whole number, representing its nuclear charge, and are only to a minor degree influenced by the mass or atomic weight of the atom.

[1] Addresses given at the celebration of the centenary of the founding of the Franklin Institute of Pennsylvania at Philadelphia, published here by the authority of the officers of the institute.

This minute but massive nucleus is, in a sense, a world of its own which is little, if at all, influenced by the ordinary physical and chemical forces at our command. In many respects, the problem of nuclear structure is much more difficult than the corresponding problem of the arrangement and motions of the planetary electrons where we have a wealth of available information, both physical and chemical, to test the adequacy of our theories. The facts known about the nucleus are few in number and the methods of attack to throw light on its structure are limited in scope.

It is convenient to distinguish between the properties assigned to the nucleus and the planetary electrons. The movements of the outer electrons are responsible for the X-ray and optical spectra of the elements and their configuration for the ordinary physical and chemical properties of the element. On the other hand, the phenomena of radioactivity and all properties that depend on the mass of the atom are to be definitely assigned to the nucleus. From a study of the radioactivity transformations, we know that the nucleus of a heavy atom not only contains positively charged bodies but also negative electrons, so that the nuclear charge is the excess of positive charge over negative. In recent years, the general idea has arisen that there are two definite fundamental units that have to do with the building up of complex nuclei, *viz.*, the light negative electron and the relatively massive hydrogen nucleus which is believed to correspond to the positive electron.

This view has received very strong support from the experiments of Aston on isotopes in which he has shown that the masses of the various species of atoms are represented nearly by whole numbers in terms of $O = 16$. From the general electric theory, it is to be anticipated that the mass of the hydrogen nucleus in the nucleus structure will be somewhat less than its value 1.0077 in the free state on account of the very close packing of the charged units in the concentrated nucleus. From Aston's experiments, it appears that the average mass of the hydrogen nucleus or proton, as it is now generally called, is very nearly 1.000 under these conditions. We should anticipate that the whole number rule found by Aston would hold only to a first approximation since the mass of the proton must be to some extent dependent on the detailed structure of the nucleus. In the case of tin and xenon, Aston has already signalized a definite departure from the whole number rule and no doubt a still more accurate determination of the masses of the atoms will disclose other differences of a similar kind.

While our present evidence indicates that the proton and electron are the fundamental constituents of the nucleus, it is very probable that secondary combining units play a prominent part in

nuclear constitution. For example, the expulsion of helium nuclei from the radioactive bodies indicates that the helium nucleus of mass four is probably a secondary unit of great importance in atom building. On the views outlined, we should expect the helium nucleus of charge two to be built up of four protons and two electrons. The loss of mass in forming this nucleus indicates that a large amount of energy must be liberated during its formation. If this be the case, the helium nucleus must be such a stable structure that the combined energy of four or five of the swiftest α particles would be necessary to effect its disruption. Such a deduction is supported by our failure to observe any evidence of disintegration of the swift particle itself, whether it is used to bombard matter or whether the α particle is used to bombard other helium atoms.

On these views, we should anticipate that the nucleus of radium of atomic number 88 and atomic weight 226 contains in all 226 protons of mass 1. and 138 electrons. While this gives us the numerical relation between the two fundamental units, we have, at present, no definite information of their arrangement in the minute nuclear volume nor of the nature and magnitude of the forces that hold them together. We should anticipate that many of the protons and electrons unite to form secondary units, *e.g.*, helium nuclei, and that the detailed structure of the nucleus may be very different from that to be expected if it consists of a conglomeration of free protons and electrons.

It is thus of great importance to obtain definite evidence of the nature and arrangement of the components of the nucleus and of the forces that hold them in equilibrium. We shall now consider some of the lines of evidence which throw light on the actual dimensions of the nucleus and the law of force operative in its neighborhood; the structure and modes of vibration of the nucleus together with the effects observed when some light nuclei are disintegrated by bombardment with particles.

Dimensions of the Nuclei and the Law of Force

The conception of the nucleus atom had its origin in 1911 in order to explain the scattering of an α particle through a large angle as the result of a single collision. The observation that the α particle is in some cases deflected through more than a right angle as the result of an encounter with a single atom first brought to light the intense forces that exist close to the nucleus. Geiger and Marsden showed that the number of particles scattered through different angles was in close accord with the simple theory which supposed that, for the distance involved, the α particle and nucleus behaved like charged points repelling each other according to the law of the

inverse square. The accuracy of this law has been independently verified by Chadwick, so that we are now certain that in a region close to the nucleus the ordinary laws of force are valid.

These scattering experiments also gave us the first idea as to the probable dimensions of the nuclei of heavy atoms, for it is to be anticipated that the law of the inverse square must break down if the α particle approaches closely to, or actually enters the nuclear structure. This variation in the law of force would show itself by a difference between the observed and calculated numbers of particles scattered through large angles. Geiger and Marsden, however, observed no certain variation even when the α particles of range about 4 cms were scattered through 100° by a gold nucleus. In such an encounter, the closest distance of approach of the particle to the center of the nucleus is about 5×10^{-12} cm, so that it would appear that the radius of the gold nucleus, assumed spherical, could not be much greater than this value.

There is another argument, based on radioactive data, which gives a similar value for the dimensions of the radius of a heavy atom. The α particle escaping from the nucleus increases in energy as it passes through the repulsive field of the nucleus. To fix a minimum limit, suppose the α particle from uranium gains all its energy from the electrostatic field. It can be calculated on these data that the radius of the uranium nucleus can not be less than 6×10^{-12} cm. This is based on the assumption that the forces outside the nucleus are repulsive and purely electrostatic. If, as seems not unlikely, there also exists close to the nucleus strong attractive forces, varying more rapidly than an inverse square law, the actual dimensions may be less than the value calculated above.

At this stage of our knowledge, it is of great importance to test whether the law of force breaks down for the distance of closest approach of an α particle to a nucleus. This can be done by comparing the observed with the calculated number of α particles scattered through angles of nearly 180°. It seems almost certain that the inverse square law must break down when swift α particles are used. This can be seen from the following simple argument. If an α particle, of the same speed as that ejected during the transformation of uranium, is fired directly at the uranium nucleus, *it must penetrate into the nuclear structure.* If a still swifter α particle is used, *e.g.*, that from radium C, which has about twice the energy of the uranium α particle, it is clear that it must penetrate still more deeply into the nuclear structure. This is based on the assumption that the field due to a nucleus is approximately symmetrical in all directions. If this is not true, it may happen

that only a fraction of the head-on collisions may be effective in penetrating the nucleus. It is hoped soon to attack this difficult problem experimentally.

We have so far dealt with collisions of an α particle with a heavy atom. We know, however, from the results of Rutherford, Chadwick and Bieler that in a collision of an α particle with the lightest atom, hydrogen, the law of the inverse square breaks down entirely when swift particles are used. Not only are the numbers of H nuclei set in swift motion much greater than is to be expected in the simple-point nucleus theory, but the change of number with the velocity of the α particle varies in the opposite way from the simple theory. Such wide departures between theory and experiment are only explicable if we assume either that the nuclei have sensible dimensions or that the inverse square law of repulsion entirely breaks down in such close collisions. If we suppose the complexity in structure and in laws of force is to be ascribed to the α particle rather than to the hydrogen nucleus, Chadwick and Bieler, as the result of a careful series of experiments, concluded that the α particle behaved as if it were a perfectly elastic body, spheroidal in shape with its minor axis at 4×10^{-13} cms in the direction of motion and major axis 8×10^{-13} cms. Outside this spheroidal region, the forces fell off according to the ordinary inverse square law, but inside this region the forces increased so rapidly that a particle was reflected from it as from a perfectly elastic body. No doubt such a conception is somewhat artificial, but it does serve to bring out the essential points involved in the collision, *viz.*, that when the nuclei approach within a certain critical distance of each other, forces come into play which vary more rapidly than the inverse square. It is difficult to ascribe this breakdown of the law of force merely to the finite size or complexity of the nuclear structure or to its distortion, but the results rather point to the presence of new and unexpected forces which come into play at such small distances. This view has been confirmed by some recent experiments of Bieler in the Cavendish Laboratory in which he has made, by scattering methods, a detailed examination of the law of force in the neighborhood of a light nucleus like that of aluminum. For this purpose he compared the relative number of α particles scattered within the same angular limit from aluminum and from gold. For the range of angles employed, *viz.*, up to 100°, it is assumed that the scattering of gold follows the inverse square law. He found that the ratio of the scattering in aluminum compared with that in gold depended on the velocity of the α particle. For example, for an α particle of 3.4 cm range, the theoretical ratio

was obtained for angles of deflection below 40° but was about 7 per cent. lower for an average angle of deflection of 80°. On the other hand, for swifter particles of range 6.6 cms, a departure from the theoretical ratio was much more marked and amounted to 29 per cent. for an angle of 80°. In order to account for these results he supposes that close to the aluminum nucleus, an attractive force is superimposed on the ordinary repulsive forces. The results agreed best with the assumption that the attractive force varies according to the inverse fourth power of the distance and that the forces of attraction and repulsion balanced at about 3 4 c 10^{-13} cms from the nuclear center. Inside this critical radius, the forces are entirely attractive; outside it they are repulsive.

While we need not lay too much stress on the accuracy of the actual value obtained or of the law of attractive force, we shall probably not be far in error in supposing the radius of the aluminum nucleus is not greater than 4×10^{-13} cm. It is of interest to note that the forces between an α particle and a hydrogen nucleus were found to vary rapidly at about the same distance.

It thus seems clear that the dimensions of the nuclei of light atoms are small, and almost unexpectedly small, in the case of aluminum, when we remember that 27 protons and 14 electrons are concentrated in such a minute region. The view that the forces between nuclei change from repulsion to attraction when they are very close together seems very probable, for otherwise it is exceedingly difficult to understand why a heavy nucleus with a large excess of positive charge can hold together in such a confined region. We shall see that the evidence from various other directions supports such a conception, but it is very unlikely that the attractive forces close to a complex nucleus can be expressed by any simple power law.

Radioactive Evidence

A study of the long series of transformations which occur in uranium and thorium provides us with a wealth of information on the modes disintegration of atoms, but unfortunately our theories of nuclear structure are not sufficiently advanced to interpret these data with any detail. The expulsion of high speed α and β particles from the radioactive nucleus gives us some idea of the powerful forces resident in the nucleus, for it can be estimated that the energy of emission of the α particle is in some cases greater than the energy that would be acquired if the particle fell freely between two points differing in potential by about four million volts. The energies of the β and γ rays are on a similar scale of magnitude.

Notwithstanding our detailed knowledge of the successive transformation of the radio elements, we have not so far been able to

obtain any definite idea of their nuclear structure, while the cause of the disintegration is still a complete figure. In comparing the uranium, thorium and actinium series of transformations, one can not fail to be struck by the many points of similarity in their modes of disintegration. Not only are the radiations similar in type and in energy but, in all cases, the end product is believed to be an isotope of lead. This remarkable similarity in the modes of transformation is especially exemplified in the case of the "C" bodies, each of which is known to break up in at least two distinct ways, giving rise to branch products. For example, thorium C emits two types of α rays, 65 per cent. of range 8.6 cms, and 35 per cent. of range 4.8 cms, and in addition some β rays.

In order to explain these results, it has been suggested that a fraction of the atoms of thorium C break up first with the expulsion of an α particle and the resulting product then emits a β particle. The other fraction breaks up in a reverse way, first expelling a β particle, while the subsequent product emits an α particle. Similar dual changes occur in radium C and actinium C, although the relative number of atoms in each branch varies widely for the different elements.

This remarkable similarity between the "C" bodies is still further emphasized by the recent discovery of Bates and Rogers that both radium C and thorium C give rise in small numbers to other groups of α particles, some of them moving at very high speeds.

It has often been a matter of remark that the radioactive properties of the "C" bodies seem to depend more on the atomic number, *i.e.*, the nuclear charge, than on the atomic weight. Confining our attention to radium C and thorium C, which are best known, both have a nuclear charge 83, but the atomic mass of radium C is 214 and of thorium C 212. The nucleus of radium C thus contains two protons and two electrons more than that of thorium C. If it were supposed that the nuclei of these elements consisted of a large number of charged units in ceaseless and irregular motion, it is to be anticipated that the addition of the protons and electrons to the complex structure would entirely alter the nuclear arrangement and consequently its stability and mode of transformation. On the other hand, we find that the modes of transformation of these two nuclei have striking and unexpected points of resemblance which are in entire disaccord with such a supposition. We can, however, suggest a possible explanation of this anomaly by supposing that the α and β particles which are liberated from these elements are not built deep into the nuclear structure but exist as *satellites* of a central core which is common to both elements. These satellites, if

in motion, may be held in equilibrium by the attractive forces arising from the core and these forces would be the same for both elements. On this view the manifestations of radioactivity are to be ascribed, not to the main core, but to the satellite distribution, which must be somewhat different for the two elements, although possibly showing many points of similarity. It must be admitted that a theory of this kind is highly speculative, but it does provide a useful working hypothesis, not only to account for the similarity of the modes of transformation of the two elements but also immediately suggests a possible explanation of the liberation of a number of α particles of different ranges from the same element. There are two ways of regarding this question. We may in the first place suppose that a certain amount of surplus energy has to be liberated in the disintegration and that this energy may be given to any one of a number of satellites. There will be a certain probability that any particular particle will be given this energy and on this will depend the relative number of particles in the different α ray groups. The ultimate energy of ejection of an α particle will depend on its position in the field of force surrounding the inner core at the moment of its liberation. On the other hand, we may suppose that the same α particle is always ejected, but that the particle may occupy in the atom one of a number of "stationary" positions analogous to the "stationary states" of the electrons in Bohr's theory of the outer atom. This rests on the assumption that all the atoms will not be identical in satellite structure, but there will be a number of possible "excited" states of the atom as a consequence of the previous disintegrations. This satellite theory is useful in another connection. It has been suggested that possibly the high frequency γ rays from a radioactive atom may arise not from the movement of the electrons as ordinarily supposed, but from the transfer of particles from one level to another. In such a case, the difference in energies between the various groups of α particles from radium C and thorium C should be connected by the quantum relation with the frequencies of prominent γ rays. The evidence at present available is not definite enough to give a final decision on this problem but points to the need of very accurate measurements of the energies of the various groups of α particles. On account of the relatively small number of particles in some of the groups, this is difficult of accomplishment.

In considering the satellite theory in connection with the radioactive bodies, it is at first sight natural to suppose, since the end product of both the radium and thorium series is an isotope of lead, that one of the isotopes of lead forms the central core. It may, however, well be that the radioactive processes cease when there are

still a number of satellites remaining. If this be so, the core may be of smaller nuclear charge and mass than that of lead. From some considerations, described later, this core may correspond to an element near platinum of number 77 and mass 192.

Frequency of Vibration of the Nucleus

One of the most interesting and important methods of throwing light on nuclear structure is the study of the very penetrating γ rays expelled by some radioactive bodies. The γ rays are identical in nature with X-rays, but the most penetrating type of rays consists of waves of much higher frequency than can be produced in an ordinary X-ray tube. The work of the last few years has indicated very clearly that the major part of the radiation from bodies, like radium B and C, originates in the nucleus. A determination of the frequencies of the γ rays thus gives us direct information on the modes of vibration of parts of the nuclear structure. The frequency of some of the softer γ rays excited by radium B and radium C were measured by the crystal method by Rutherford and Andrade, but it is difficult, if not impossible, by this method to determine the frequencies of the very penetrating rays. Fortunately, due largely to the work of Ellis and Fraulein Meitner, a new and powerful method has been devised for this purpose. It is well known that the β rays from radium B and radium C give a veritable spectrum in a magnetic field showing the presence of a number of groups of β rays each expelled with a definite speed. It is clear that each of the groups of β rays arises from conversion of the energy of a γ ray of definite frequency into a β ray in one or other of the electronic levels in the outer atom. The energy ω required to move an electron from one of these levels to the outside of the atom is known from a study of X-ray absorption spectra. The frequency γ of the γ ray is thus given by the quantum relation $h\nu = E + \omega$, where E is the measured energy of the β particle.

Since each γ ray may be converted in any one of the known electronic levels in the outer atom, a single γ ray is responsible for the appearance of a number of groups of β rays, corresponding to conversion in the K, L, M, etc., levels. In this way, an analysis of the β ray spectrum allows us to fix the frequency of the more intense γ rays which are emitted from the nucleus. The energy of the shortest wave measured in this way by Ellis corresponds to more than two million volts, while other evidence shows that probably still shorter waves are emitted in small quantity from radium C.

Ellis and Skinner have shown that the energies of these rays show certain combination differences, such as are so characteristic of the energies of the X-rays arising from the outer electrons. A

series of energy levels may thus be postulated in the nucleus similar in character to the electron levels of the outer atom and the γ rays have their origin in the fall, either of an electron or of an α particle between these levels. This is a significant and important result indicating that the quantum dynamics can be applied to the nucleus as well as to the outer electronic structure.

The probability of levels in the nuclear structure is most clearly seen on the satellite hypothesis, but in our ignorance of the laws of force near the core, we are at the moment unable to apply the quantum dynamics directly to the problem. The outlook for further advances in this direction is hopeful, but is intimately connected with further development of our knowledge of the laws of force that come into play close to the nucleus in the region occupied by the satellites.

Artificial Disintegration of Elements

We have seen that it is believed that the nuclei of all atoms are composed of protons and electrons and that the number of each of these units in any nucleus can be deduced from its mass and nuclear charge. It is, however, at first sight rather surprising that no evidence of the individual existence of protons in a nucleus is obtained from a study of the transformations of the radioactive elements, where the processes occurring must be supposed to be of a very fundamental character. As far as our observations have gone electrons and helium nuclei but no protons are ejected during the long series of transformations of uranium, thorium and actinium. One of the most obvious methods for determining the structure of a nucleus is to find a method of disintegrating it into its component parts. This is done spontaneously for us by nature to a limited extent in the case of the heavy radioactive elements, but evidence of this character is not available in the case of the ordinary elements. As the swift α particle from the radioactive bodies is, by far, the most energetic projectile known to us, it seemed from the first possible that occasionally the nucleus of a light atom might be disintegrated as the result of a close collision with an α particle. On account of the minute size of the nucleus, it is to be anticipated that the chance of a direct hit would be very small and that consequently the disintegration effects, if any, would be observed only on a very minute scale. During the last few years, Dr. Chadwick and I have obtained definite evidence that hydrogen nuclei or protons can be removed by bombardment of α particles from the elements boron, nitrogen, fluorine, sodium, aluminum and phosphorus. In these experiments, the presence of H nuclei is detected by the scintillation method, and their maximum velocity of ejection can be estimated from the thickness of matter which can be penetrated by these particles. The

number of H nuclei ejected even in the most favorable case is relatively very small compared with the number of bombarding α particles, *viz.*, about one in a million.

In these experiments the material subject to bombardment was placed immediately in front of the source of α particles and observations on the ejected particles were made on a zinc sulphide screen placed in a direct line a few centimeters away. Using radium C as a source of α rays, the ranges of penetration expressed in terms of centimeters of air were in all these cases greater than the range of free nuclei (30 cms in air) set in motion in hydrogen by the α particles. By inserting absorbing screens of 30 cms air equivalent in front of the zinc sulphide screen the results were quite independent of the presence of either free or combined hydrogen as an impurity in the bombarded materials. Some of the lighter elements were examined for absorptions less than this but, in general, the number of H particles due to hydrogen contamination of the source and the materials was so large that no confidence could be placed in the results.

In such experiments many scintillations can be observed, but it is very difficult to decide whether these can be ascribed in part to an actual disintegration of the material under examination. The presence of long range particles of the α ray type from the source of radium C still further complicates the question, since in general the number of such particles is large compared with the disintegration effect we usually observe.

To overcome these difficulties, inherent in the direct method of observation, Dr. Chadwick and I have devised a simple method by which we can observe with certainty the disintegration of an element when the ejected particles have a range of only 7 cms in air. This method is based on the assumption, verified in our previous experiments, that the disintegration particles are emitted in all directions relative to the incident rays. A powerful beam of α rays falls on the material to be examined and the liberated particles are observed at an average angle of 90° to the direction of the incident α particles. By means of screens it is arranged that no α particles can fall directly on the zinc sulphide screen.

This method has many advantages. We can now detect particles of range more than 7 cms, with the same certainty as particles of range above 30 cms, in our previous experiments, for the presence of hydrogen in the bombarded material has no effect. This can be shown at once by bombarding a screen of paraffin wax, when no particles are observed on the zinc sulphide screen. On account of the very great reduction in number of H nuclei or α particles by scattering through 90°, the results are quite independent of

H nuclei from the source or of the long range α particles. The latter are just detectable under our experimental conditions when a heavy element like gold is used as scattering material, but are inappreciable for the lighter elements.

A slight modification of the arrangement enables us to examine gases as well as solids.

Working in this way we have found that in addition to the elements boron, nitrogen, fluorine, sodium, aluminum and phosphorus, which give H particles of maximum range in the forward direction between 40 and 90 cms, the following give particles of range above 7 cms, neon, magnesium, silicon, sulphur, chlorine, argon and potassium. The numbers of the particles emitted from these elements are small compared with the number from aluminum under the same conditions, varying between one third and one twentieth. The ranges of the particles have not been determined with accuracy. Neon appears to give the shortest range, about 16 cm, under our conditions, the ranges of the others lying between 18 cm and 30 cm. By the kindness of Dr. Rosenhain we were able to make experiments with a sheet of metallic beryllium. This gave a small effect about one thirtieth of that of aluminum, but we are not yet certain that it may not be due to the presence of a small quantity of fluorine as an impurity. The other light elements, hydrogen, helium, lithium, carbon and oxygen, give no detectable effect beyond 7 cm. It is of interest to note that while carbon and oxygen give no effect, sulphur, also probably a "pure" element of mass 4n, gives an effect of nearly one third that of aluminum. This shows clearly that the sulphur nucleus is not built up solely of helium nuclei, a conclusion also suggested by its atomic weight of 32.07.

We have made a preliminary examination of the elements from calcium to iron, but with no definite results, owing to the difficulty of obtaining these elements free from any of the "active" elements, in particular, nitrogen. For example, while a piece of electrolytic iron gave no particles beyond 7 cms, a piece of Swedish iron gave a large effect which was undoubtedly due to the presence of nitrogen, for after prolonged heating *in vacuo* the greater part disappeared. Similar results were experienced with the other elements in this region.

We have observed no effects from the following elements: nickel, copper, zinc, selenium, krypton, molybdenum, palladium, silver, tin, xenon, gold and uranium. The krypton and xenon were kindly lent by Dr. Aston.

Examination of Light Elements for Particles of Range less than 3 cms of Air

When α particles are scattered from light elements, the simple theory shows that the velocity of the scattered particles depends on the angle of scattering. For example, using bombarding α particles of range 7 cms, the range of the α particles scattered through more than 90° can not be greater than 1.0 cms for lithium (7), 2.0 cms for beryllium, (10), 2.5 cms for carbon, 3.2 cms for oxygen, 4.3 cms for aluminum and 6.8 cms for gold.

Provided we introduce sufficient thickness of absorber to stop the α particles scattered through 90°, we can examine for disintegrated particles from carbon, for example, whose range exceeds 2.5 cms. Certain difficulties arise in this type of experiment which are absent when the thickness of absorber is greater than 7 cms; any heavy elements present as an impurity will give scattered α particles of range greater than those from carbon and thus complicate the observations. In addition, serious troubles may arise due to the volatilization or escape of active matter from the source. This is especially marked if the vessel containing the radioactive source is exhausted. To overcome this difficulty, we have found it desirable to cover the source with a thin layer of celluloid of 2 or 3 mm stopping power for α rays. By this procedure, we have been able to avoid serious contamination and to examine the lighter elements by this method. We have been unable to detect any appreciable number of particles from lithium or carbon for ranges greater than 3 cms. If carbon shows any effect at all, it is certainly less than one tenth of the number from aluminum under the same conditions. This is in entire disagreement with the work of Kirsch and Patterson (*Nature,* April 26, 1924), who found evidence of a large number of particles from carbon of range 6 cms. A slight effect was observed in beryllium in accordance with our other experiments. No effect was noted in oxygen gas. Apart from beryllium, no certain effect has been noted for elements lighter than boron.

Under the conditions of our experiment, it seems clear that neither H nuclei nor other particles of range greater than 3 cms can be liberated in appreciable numbers from these elements in a direction at right angles to the bombarding α rays. This is, in a sense, a disappointing result, for, unless these elements are very firmly bound structures, it was to be anticipated that an α particle bombardment would receive them into their constituent particles.

We hope to examine this whole question still more thoroughly, as it is a matter of great importance to the theory of nuclear constitution to be certain whether or not the light elements can be discharged by swift α particles.

In considering the results of our new and old observations, some points of striking interest emerge. In the first place, all the elements from fluorine to potassium, inclusive, suffer disintegration under α ray bombardment. As far as our observations have gone, there seems little doubt that the particles ejected from all these elements are H nuclei. The odd elements B, N, Fl, Wa, Al, P, all give long range particles varying in range from 40 cms to 90 cms in the forward direction; the even elements C, O, Ne, Mg, Si, S, either give few or none at all, as in the case of C and O, or give particles of much less range than the adjacent odd-numbered elements. The difference between the range of even–odd elements becomes much less marked for elements heavier than phosphorus.

This obvious difference in velocity of expulsion of the H nuclei from even and odd elements is a matter of great interest. Such a distinction can be paralleled by other observations of an entirely different character. Harkins has shown that elements of even atomic number are much more abundant in the earth's crust than elements of odd atomic number. In his study of isotopes, Aston has shown that in general odd-numbered elements have only two isotopes differing in mass by two units, while even-numbered elements in some cases contain a large number of isotopes. This remarkable distinction between even and odd elements can not but excite a lively curiosity, but we can at present only speculate on its underlying cause.

Velocity of Escape of Hydrogen Nuclei

We have seen that the experiments of Bieler on the scattering of X-rays by aluminum and magnesium indicate that a powerful attractive force comes into play very close to the nuclei of these atoms. If this be the case, the forces of attraction and repulsion must balance at a certain distance from the nucleus. Outside this critical point the forces on a positively charged body are entirely repulsive. Certain important consequences follow from this general view of nuclear forces. Suppose, for example, that, due to a collision with a swift α particle, a hydrogen nucleus is liberated from the nuclear structure. After passing across the critical surface, it will acquire energy in passing through the repulsive field. It is clear, on this view, that the energy of a charged particle after escape from the atom can not be less than the energy acquired in the repulsive field; consequently we should expect to find evidence that there is a minimum velocity of escape of a disintegration particle. We have obtained definite evidence of such an effect both in aluminum and sulphur by examining the absorption of H nuclei from these elements. The number of scintillations for a thin film

was found to be nearly constant for absorption between 7 and 12 cms, but falls off rapidly for greater thickness. This is exactly what is to be expected on the views outlined. No doubt the limiting velocity varies somewhat for the different elements, but a large amount of experiment will be required to fix this limit with accuracy. From these results, it is possible to form a rough estimate of the potential of the field at the critical surface and this comes out to be about three million volts for aluminum. The value for sulphur is somewhat greater. This brings out in a striking way the extraordinary smallness of the nuclei of these elements, for it can be calculated that the critical surface can not be distant more than 6×10^{-13} cm from the center of the nucleus. These deductions of the critical distance are in excellent accord with those made by Bieler from observations of the scattering of α particles.

Another important consequence follows. It is clear that an α particle fired at the nucleus will not be able to cross this critical surface and thus be in a position to produce disintegration, unless its velocity exceeds that corresponding to the critical potential. In an experiment made a few years ago, we found that the number of H nuclei liberated from aluminum fell off rapidly with diminution of the velocity of the α particle and was too small in number to detect when the range of the α particle was less than 4.9 cms. This corresponds to the energy of an α particle falling between about three million volts—a value in good accord with that calculated from the escape of H nuclei.

Further experiments are required with other elements to test if this relation between the minimum velocity of H nuclei and the minimum velocity of the α particle to produce disintegration, holds generally; but the results as far as they go are certainly very suggestive.

It is of interest to note that these results afford a definite proof of the nuclear conception of the atom and give us some hope that we may determine the magnitude of the critical potential for a number of the light elements.

Evolution of Nuclei

In concluding, I would like to make a few remarks of a more speculative character dealing with the fundamental problem of the origin and evolution of the elements from the two fundamental building units, the positive and negative electrons. It must be confessed that there is little information to guide us with the exception of our knowledge of the nuclear charges and masses of the various species of elements which survive to-day. It has always been a matter of great difficulty to imagine how the more complex nuclei

can be built up by the successive additions of protons and electrons, since the proton must be endowed with a very high speed to approach closely to the charged nucleus. I have already discussed in this paper the evidence that powerful attractive forces varying very rapidly with the distance are present close to the nuclear structure and it seems probable that these forces must ultimately be ascribed to the constituent proton. In such a case, it may be possible for an electron and proton to form a very close combination, or neutron, as I have termed it. The probable distance between the center of this doublet is of the order of 3×10^{-18} cms. The forces between the two neutrons would be very small except for distance of approach of this order of magnitude, and it is probable that the neutrons would collect together in much the same fashion as a number of small movable magnets would tend to form a coherent group held together by their mutual forces.

In considering the origin of the elements, we may for simplicity suppose a large diffused mass of hydrogen which is gradually heated by its gravitational condensation. At high temperatures, the gas would consist mainly of free hydrogen nuclei and electrons, and some of these would in course of time combine to form neutrons emitting energy in the process. These neutrons would collect together in nuclear masses of all kinds of complexity. Now the tendency of the groups of neutrons would be to form more stable nuclear combinations, such as helium nuclei of mass four, and possibly intermediate stages of masses two and three. Energy would be emitted in these processes probably in the form of swift surplus electrons which were not necessary for the stability of the system. In a sense, all these nuclear masses would be radioactive, but some of them in their transformation may reach a stable configuration which would represent the nucleus of one of our surviving elements. If we suppose that nuclear masses over a wide range of mass can be formed before serious transformation occurs, it is easy to see how every possible type of stable element will gradually emerge. If we take the helium nucleus as a combining unit which emits in its formation the greatest amount of energy we should ultimately expect many of the neutrons in a heavy nucleus to form helium nuclei. These helium nuclei would tend to collect together and form definite systems and it seems not unlikely that they will group themselves into orderly structures, analogous in some respects to the regular arrangement of atoms to form crystals, but with much smaller distances between the structural units. In such a case, some of the elements may consist of a central crystal type of structure of helium nuclei surrounded by positive and negatively charged satellites in motion round this central core. Assuming that such orderly

arrangements of helium nuclei are possible, it is of interest to note that the observed relations between atomic charges and atomic mass for the elements can be approximately obtained on a very simple assumption. Suppose that helium nuclei form a point centered cubic lattice with an electron at the center of a crystal unit of eight helium nuclei. A few of the possible types of grouping are given in the following table with corresponding masses and nuclear charges. The structure 4. 3. 2. means a rectangular arrangement with sides containing 4. 3. 2. nuclei, respectively. It will thus contain 24 helium nuclei, have a mass 96, and will contain 6 intranuclear electrons. Its nuclear charge will therefore be $48 - 6 = 42$.

Structural arrangement of helium nuclei	Calculated nuclear charge	Calculated mass	Known element of equal charge
3. 2. 2.	22	48	Ti 48
3. 3. 2.	32	72	Ge 74, 72, 70
3. 3. 3.	46	108	Pa 106.7
4. 2. 2.	29	64	Cu 63.35
4. 3. 2.	42	96	Mo 96
4. 3. 3.	60	144	Nd 144
4. 4. 3.	78	192	Pt 195

While the arrangement is far from perfect for all these structures, there is a general accord with observation. If we take the view that some of these structures can grow by the addition of satellites, there is room for adjustment of masses and to include the intervening elements. This point of view is admittedly very speculative, and there may well be other types of structure involved. At the same time, the general evidence suggests that there are some basal structures on which the heavier atoms are progressively built up. The failure of the whole number rule for the mass of isotopes, observed in some cases by Aston, *e.g.*, between tin and xenon, certainly supports such a conception. From a study of the artificial disintegration of the elements we have seen that carbon and oxygen represent very stable structures probably composed of helium nuclei. It is possible that oxygen nuclei, for example, may be the structural basis of some of the elements following oxygen, but our information is at present too meager to be at all certain on this point.

I think, however, it will be clear from this lecture what a difficult but fascinating problem is involved in the structure of nuclei. Before we can hope to make much advance, it is essential to know more of the nature of the forces operative close to protons and electrons, and we may hope to acquire much information by a detailed study of the scattering of swift α rays and β rays by nuclei. Fortunately, there is now a number of distinct lines of attack in

this problem, and from a combination of the results obtained, we may hope to make steady, if not rapid, progress in the solution of this, the greatest problem in physics.

THE CARBON ATOM IN CRYSTALLINE STRUCTURE

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It is one of the great purposes of research to be able to explain the properties of materials in terms of the properties of their parts. The division into parts may be carried to various degrees of fineness; and the nature of the research, its methods and difficulties, and the expectations of success will depend on the division that is attempted. The properties of a piece of steel may to some extent be explained in terms of the small visible particles, crystalline or of which it is composed; the degree of division is determined by the power of the microscope, and results of great value are obtained within this range. But we may have, as a higher ideal, the hope of explaining the qualities of steel in terms of the properties of the atoms of iron and carbon and other constituent elements. The division is far finer than the other; but obviously far more complete and satisfying. The difficulties are great, but so also will be, we may be sure, the ultimate success. And generally it must be our aim to explain the properties of all materials in terms of the atoms, remarkably limited in kind, of which the world is made.

Some progress towards the ideal has been made in the case of the gas and the liquid states; the great effort is yet to be made in the case of the solid. The moving particles of a gas are free from each other's influence for the most part of their time; they can be heated as projectiles whose rare encounters are but slightly affected by the special and peculiar attractions which they exert on each other when very close together. The properties of gases are to a certain extent explainable in terms of a pure kinetic theory. Complications arise when from any cause the times during which the atoms or molecules are under each other's influence become relatively important, and the consequences depend on the individual peculiarities.

So also in the case of liquids much can be explained on a purely hydrodynamical theory, especially when the ties between atoms and molecules can be dissolved and reformed continually without waste of energy in the form of heat, that is to say, when there are no viscosity effects. But when viscosity is to be taken account of, then the peculiar and individual actions of the atoms and molecules must be treated as effective. Still more, the phenomena of surface

tension are direct manifestations of the forces that the atoms exert on their neighbors; and so in general are all the effects studied by the physical chemist. We are yet very far from being able to unravel them.

It is true that the associations and dissolutions of chemical action are due directly to the characteristic forces exerted by the atoms; and that chemical studies afford a most important means of examining them. Nevertheless, we want more than chemistry gives us if we are to reach our object. For instance, we are far from linking up the properties of quartz with the known chemistry of silicon and oxygen.

In general, we know very little of the relation between the properties of the solid material and of the atoms of which it is built. Of the relation between the molecule and its constituent atoms we do know something, thanks to chemical study. But the wide field of solid structure is in this respect almost unexplored. The reason for this is very simple. The properties of the solid depend upon the structural arrangement of its component atoms which arrangement is at the first attempt, as we may say, crystalline. When groups of atoms or molecules associate and form a solid, they arrange themselves in a regular pattern; the unit of pattern containing only a few groups, usually two, three, four, six or other small numbers. The arrangement is so uniform and so exact as to imply that the group has a definite and characteristic shape, or, in other words, that the forces which one group, atom or molecule exerts on its neighbors are such as to place them at proper distances from itself and in proper orientations. The crystal is the direct expression of this tendency and is a far more prevalent form of matter than we had thought. The large crystals that we see with our naked eye, and even the small crystals which the microscope reveals to us are only the favorable cases. Below all that we can see in any way is a universal tendency to crystallization which the methods of X-ray analysis are now showing to us. The solid which appears to us to possess none of the properties of the crystal is usually a very viscous body or a disordered mass of minute crystals. The crystal is the simple body, the so-called isotopic body is the complex. Consequently, it is the crystal that must first be mastered.

It is only within the last ten years that the direct study of crystal structure has been possible and the way to this huge field of inquiry been thrown open. The X-rays, to put it simply, if somewhat crudely, are a form of light ten thousand times finer than visible light, and we are now able to see, indirectly it may be, the actual arrangement of the atoms. Here is our chance of making

this supreme analysis. We have before us a wide-spread research, in the course of which we must examine crystal after crystal, learning its structure, that is to say, the pattern according to which its constituent atoms are arranged, and examining the way in which the properties of the individuals determine that pattern and in turn the pattern determines the elasticities, rigidities, conductivities, dielectric capacities and every other characteristic which the crystal possesses. After that, follows in its turn the crystal conglomerate, the isotropic solid.

An especial interest is attached to all that we can discover by the new methods of crystal analysis concerning the nature and properties of the carbon atom. It is not one of the more common elements. While oxygen is calculated to form half the materials of the earth's crust, silicon a quarter and aluminum about a sixteenth, only about a thousandth is composed of carbon. But it is the carbon atom which more than any other impresses its character on the materials of which living bodies are composed. The very term, organic chemistry, which is given to the subject that is largely occupied with the study of the carbon compounds, is an expression of the importance of the carbon atom in the living organism. And not only is the carbon molecule of supreme importance in the constitution of our bodies and of their unconscious actions, but also in a great proportion of the external activities in which we are engaged. We must be especially eager to know what we may learn of the behavior of the carbon atom when it takes part in the constitution of the solid body, and in the first place of the crystal which is the simplest form of the solid. The only fact which makes us hesitate is the vastness of the number of known crystalline compounds, giving us a bewildering choice of material on which to work.

We come to this study with certain expectations founded on the large labors of the organic chemist and their rich harvest of results. We expect the carbon atom to display, for example, a definite tetravalency, a power of attracting to itself under certain circumstances at least four other atoms and no more, all bound in a similar way to the central carbon; as, for example, when the carbon atom draws to itself four atoms of hydrogen and the methane molecule is formed. Yet, under other circumstances, the carbon atom seems fairly content with a smaller number, as when in the benzene ring each carbon is attached to two other carbons and only one hydrogen, and the benzene molecule has very little general attraction for another benzene molecule. Again in the carbon dioxide molecule, the carbon atom is satisfied by the companionship of two other atoms only, and we should like to know which re-

arrangement has been made of its activities to permit the formation of this self-contained molecule, so independent that it forms a gas. And what further change has been made when the molecule of carbon monoxide is constituted? In other words, what is the explanation of the single, double and triple bonds known to the chemist? We hope to be able to throw light on all these phenomena and the questions to which they give rise by the study of the carbon atom as it is built into the crystal where we can examine the exact nature of its evironment and can relate thereto the properties of the crystal.

There are two crystalline forms composed of carbon alone, diamond and graphite, and we naturally turn to their examination first. The diamond structure was, in fact, one of the first to be examined by the new methods. Its structure is very simple and symmetrical and answers at once our expectation that we should find under some circumstances a perfectly tetravalent behavior. Each carbon atom is surrounded by four others, which are grouped about it in perfect symmetry; the atom shows no attraction for more than four. A sphere can, of course, be surrounded by twelve other similar spheres, and if the attraction between any two atoms could be represented merely by a central force, we should expect the close packing which gives the full quota of neighbors. Since there are only four, the force exerted by one carbon atom on another can not be represented by central forces only. Further, the hardness and rigidity of the diamond show us that the forces are mutually oriented; that they are primarily exerted along four lines drawn from the center of a tetrahedron to its corners and that there is a strong resistance to any relative change in those directions. All these new points are in excellent agreement with known chemical facts. The carbon atom is to be represented by a tetrahedron rather than a sphere.

The disposition of the atoms in the diamond shows that they may be divided into two classes, any member of one class being the reflection of the other—with appropriate shift—in any one of three planes which are the cube faces of the crystal. To put this in another form, each diagonal of the cube crystal passes through the vertex and the middle of the base of each class of atom, but members of the two classes face opposite ways. The X-rays detect the difference between the two kinds, from which we conclude that the scatterers of the X-rays participate in the tetrahedral grouping. Yet the difference is only slight, so that if it is the electrons that scatter, they are either close to the center, which seems unlikely, or are not closely pinned down to the corners, so that their diffract-

ing effect would not be large; their action would be like that of broad faint rulings on a diffraction grating.

The other crystal of pure carbon is graphite. There is no clear evidence at present of the existence of any other form, although certain curious carbon matërials have not been fully examined. The structure of graphite has recently been reexamined by Bernal, who was able to obtain single crystals of sufficiently perfect form. The results of his work show that graphite is a hexagonal crystal, as Hull had supposed from an examination by the lowder method. It consists of layers of carbon atoms, each layer separated from the next by 3.40 AU, as has long been known. In each layer, the carbon atoms are arranged in a hexagonal network; the long uncertain point as to whether the atoms of one sheet are all exactly in one plane or are in two planes making a puckered network, seems now to be decided in favor of the former alternative, as Debye has suggested. In this case, each carbon atom is very strongly tied to three neighbors all in one plane; the distance between the centers is 1.44 AU as against 1.54 AU in the diamond. The distance between a carbon atom in one layer and its nearest neighbor in the next is more than twice as great. The curious properties of graphite show that the forces between atoms in the same sheet are exceedingly strong, while the forces between sheet and sheet are very small. It is clear that the carbon atom is now exerting its attraction on other atoms in quite a different manner from that which was followed in diamond. If the electrons are in some way responsible for these forces their arrangement must have been altered. The atom is no layer tetrahedral.

The extraordinary success of Bohr's theory in regard to radiation is a constant inducement to attempt a correlation between his arrangement of electron orbits with the display of the atomic forces, although it does not seem possible at present to make more than vague and preliminary attempts in this direction. According to Bohr, there are four electron orbits which we may naturally associate with the tetravalency of the atom; but the four are not all alike, being different, two and two. Thus the tetravalency is not symmetrical. The radiating carbon atom which is the subject of the theory is not, however, attached to other atoms, but is free; and we may well suppose that the internal arrangements are modified by structural requirements. There may be a real difference, implying perhaps a different energy contest between the free atom with its two pairs of outer orbits, the atom in graphite with three like orbits and one odd, and the atom in diamond with all four alike. The electron of the odd orbit in graphite would naturally travel far and be loosely attached to the nucleus; and in this, as

has been suggested by Dr. Shearer and Mr. Bernal, we may find the explanation of the color, the opacity and the conductivity of graphite.

We now come to cases in which other atoms beside the carbon enter into the structure; and first to calcite. The X-ray analysis shows that the carbon atom is now surrounded symmetrically by three atoms of oxygen, all alike.

The compact group of one carbon and three oxygens possesses a double negative charge; the calcium atom possessing the corresponding amount of positive electricity. It has been suggested by Kossel that the arrangement is governed by the tendency for the oxygen atoms to surround themselves in each case by the full complement of eight electrons, and that this is effected by stripping the calcium atom of two electrons and the carbon atom of four. On this theory there is no parallelism with the graphite structure, though in both cases the carbon atom is surrounded by three other coplanar atoms, similarly situated. The carbon atom has now lost all four of the electrons that were moving in outer orbits and is reduced, in external appearance, to helium. It is to be treated as exerting a central electrostatic force due to a positive charge of four units.

It is well known that a vast number of organic substances are based on a substructure consisting of a ring of six carbon atoms, or a chain of carbon atoms of any length. The simplest ring compound is the famous benzene molecule; benzene itself does not, however, lend itself very readily to analysis because benzene is liquid at ordinary temperature and when frozen does not form good crystals. But there are the two substances, naphthalene and anthracene, of which the former has been imagined by the organic chemist to consist of a double ring, represented by two hexagons in the same plane having one side and two corners in common. The latter consists of three hexagons in a line, the naphthalene model extended by one more hexagon. Both these substances crystallize well, a very marked characteristic of each being the tendency to split into thin flakes. All these molecules are bounded by hydrogens as shown in the diagram. They must be considered as simple subjects for attack, because the ring is so common a feature of organic substances and the single, double and triple ring form a series of comparable members. A curious point of obvious interest is the connection of each carbon atom with three, and only three, other atoms. Why has the fourth bond apparently disappeared?

The X-ray analysis shows that the unit of pattern of both naphthalene and anthracene contains two molecules arranged so that their long axes are parallel to one another and that they are the

reflection of each other in the single plane of symmetry which the crystal possesses. In fact the crystal can be considered as a set of parallel flakes, like the monomolecular layers of Langmuir, in each flake the molecules stand not quite at right angles to the flake but leaning over, like wheat in a field blown by the wind. The difference between the anthracene and the naphthalene structures lies only in the length of the molecule, which makes the flaky thickness of the former greater than that of the latter. Moreover, the actual increase in length which is found by the X-ray measurement is exactly what it should be if, in the first place, the one molecule consists of three benzene rings in a row and the other of only two, according to chemical theory, and in the second place, the width of the ring is the same as that of the carbon ring which is found everywhere in the diamond structure. We might suppose in fact that the molecule of naphthalene as built into the crystal structure was simply carved out of the diamond without alteration and then fringed with hydrogen atoms. A similar set of atoms carved out of the graphite flake would do equally well so far as length is concerned, because the graphite layer is, according to Bernal, the diamond layer pressed flat without any sideways extension. But if the carbon atoms were in the supposed graphite condition, it might be expected that naphthalene would be a conductor and opaque like graphite, which is not the case. The direct analysis itself is not yet able to say whether the three attachments of each carbon atom to its neighbors in the same molecule are all on one plane. It is to be remembered that there are attachments between each molecule and its neighbors in the same layer, but these must be far weaker than the bonds binding together the atoms in the same molecule; they are stronger, however, than the end to end attachments which break on the cleaving of the crystal. These last must be feeble because the crystal cleaves so easily.

So far, therefore, the result of the analysis of these crystals is in the first place to give confidence in the existence of a mutual support between the established organic chemistry and the new methods of analysis; and to show us also how closely the behavior of the crystal may be connected with its general structure. As to details, the indication seems to be that the carbon atom has—at least nearly so—the same characteristics as the atom of the diamond; but that one of the four valencies is unused. We have even some grounds for saying that the unused valency, or the unoccupied corner of the carbon tetrahedron is that which lies on the face of the molecule, not on its edge. The crystal of naphthalene tetrachloride, *i.e.*, naphthalene with four added chlorine atoms, shows the same structure as that of naphthalene, and has very

similar dimensions, except that it has broadened by an amount which would correspond closely with the result of adding the chlorines to the places indicated.

Measurements have been made of some of the dimensions of other crystals containing ring molecules, and the results fit in, as far as they go, with the idea that the ring is an actual structure of definite dimension and form, slightly altered it may be by additions or substitutions of other atoms or groups of atoms, or strained because it has to be fitted into its place in the crystal, nevertheless recognizable in its different circumstances, as the chemist would expect. To settle these points more satisfactorily, to turn guesses into certainties is, of course, the work that is before us.

Very interesting results are obtained from the study of the long chain molecules of the fatty acids, hydrocarbons and similar substances. It appears that when these substances in the solid state are pressed onto a flat surface, they form flaky crystals like graphite or naphthalene and it becomes easy to measure the thickness of the monomolecular layer. The experimental results are beautifully definite, and their interpretation can be given with great chance of being correct. It seems that the molecule is perpendicular to the layer, not slanting. If it were the latter, one would expect the amount of slant to be variable so that it would not be possible to connect the thickness of the layer with the length of the molecule only. Now, it is a remarkable fact that the thickness of the layer grows at a uniform rate as the chain is increased by the addition of carbon atoms and that for very nearly all if not all the different kinds of chain molecules that have been examined, this rate has one or other of two values. For every two carbon atoms that are added the increase in length is either 2.50 AU or 2.00 AU very nearly.

If we were to suppose that every carbon atom in the chain had four points on it, disposed like the corners of a regular tetrahedron, at any one of which an attachment could be made to a neighbor, in other words, if we supposed the atom to be as in diamond, then a chain of carbon atoms would take one or other of three forms, A, B, or C, the last of which is a screw. Putting the distance between the center of two carbon atoms equal to the distance found in the diamond, *viz.*, 1.54 AU, it can readily be calculated that the length of chain A is 2.50 AU for every two atoms added, and of chain B, 2.05 AU. The agreement with experiment seems to be more than a coincidence; it is justifiable to assume that in these chains either the A or the B form is adopted, and the linkage of carbon atoms with their neighbors is on the diamond plan. In other words, if PQR is the center of three atoms, the angle PQR is equal to the

angle between two of the lines joining the center of a tetrahedron to the corners.

One of the most striking results is the fact that the length of the main body of the chain is independent of the nature of any additions to its ends or replacement of any of its side hydrogens by an oxygen atom as in the ketones. Even the removal of two or four hydrogens from the body of the chain leaving two carbons connected respectively by a double or a triple bond makes no appreciable difference in the length. It would not have been a matter of surprise if such treatment had caused a bend in the chain, on account of the relative shifting of points of attachment on the carbon atom that might be due to other points of attachment being unused. The removal of a pair of hydrogens from the chain makes no more difference to the chain than the stripping of an opposing pair of leaves from the stem of a plant.

A very curious point in the behavior of the long chains is their apparent doubling in length when one end is formed of a so-called active group, as for example in the case of the fatty acids. When this is the case two chains join end to end, the active groups being together, and again the result is just the same as if two sticks were joined into one, the process of joining being concerned with nothing beyond the two active ends. This form of structure is illustrated in a very interesting way in the X-ray spectra. If a section is made of a substance consisting of layers of these doubled molecules, so as to show their stratification, then there will be a uniform distribution of diffracting centers—electrons—throughout the mass, with alternating thin layers of excess through the active ends and thin layers of deficiency through the inactive ends, the methyl groups. This has the curious effect of intensifying the odd orders of the diffraction spectra. To understand this, it is only necessary to remember that if we were to make a series of fine rulings on a diffraction grating which exactly interleaved the stronger original rulings, the result would be the strengthening of the even orders; such an effect is found in the case of rock salt and was an important help in the determination of its structure. If now the additional rulings, instead of being like the original but weaker, could be of reversed effect, a deficiency instead of an excess, it would be the odd, not the every order that would be strengthened. The same effect is found in the case of the ketones. When the substituted oxygen is in the middle of the chain, each layer of hydrocarbon molecules shows a generally uniform distribution of electrons with an excess at the middle where the oxygen atom is placed and a deficiency at either end. When the substituted oxygen is not in the middle the reinforcement of the odd orders disappears.

These many observations of the behavior of the long chain molecules seem to point to the conclusion that the carbon atom in the chain is, like the carbon atom in the diamond atom, possessed of four points of attachment regularly disposed about it, and that the non-use of one does not alter the disposition of the others.

It is scarcely necessary to consider in any detail the points given by structures like tartaric or succinic acid as to the behavior of carbon atom. It is enough to say that, while the full interpretation is yet to come, the general indications are in accordance with what has already been said.

I have thought it might be of interest to consider these first tentative conclusions as to the behavior of the carbon atom in the solid body, in spite of the fact that so little, relatively, has been accomplished in the solution of the structure of organic crystals. What is to be done must have great consequences, and what little has been done already seems to possess many points of novelty and of interest, and these two facts taken together may be sufficient justification for my attempt at a review of the present position of the inquiry.

THE BEST USE OF THE WATERS OF THE GREAT LAKES

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MAN'S progress is dependent largely upon his development of good transportation, upon his use of mechanical power and upon his success in conquering disease.

If the reader has any doubt as to whether man's progress depends upon transportation let him look at good maps and note the evident relation between well-developed lines of water and railway transportation and the degree of civilization in the vicinity of those routes.

The substitution of mechanical power for the muscles of man and beasts is the basis of our modern industrial system in which each man actually turns out four times as much useful production as would otherwise be possible.[1]

Man's conquest over germ-borne disease has reopened the tropics to the conquest of the white man. In the days of poor sanitation cities were the homes of diseases. To-day a man has a better chance of long life, thorough physical development and freedom from disease in the cities than he has in the country.

We should develop transportation, cheap power and sanitation to the best of our ability. The waters of the Great Lakes may be made to help greatly in all three of these things.

Formerly many engineers believed that their help should be limited to the technical side in supplying transportation, power and sanitation. Now engineers believe that it is a part of their work in the world to help in the promotion, the advance work, the educational work, involved in these three things. I certainly believe strongly in that idea.

There are the Great Lakes. There is a drop of 21 feet between Lake Superior and Lake Huron, which is mainly in the rapids at the Sault locks. Note on the chart the elevations above sea level in feet marked on each of the lakes. Lake Michigan and Lake Huron together form one lake, all at elevation 581 feet above sea level. There is a drop of only 8 feet from Lake Huron to Lake Erie. There is a drop of 327 feet from Lake Erie to Lake Ontario, of which but little more than one half is in Niagara Falls. The

[1] "The Discovery of Truth in Universities," by Walter Dill Scott, p. 6.

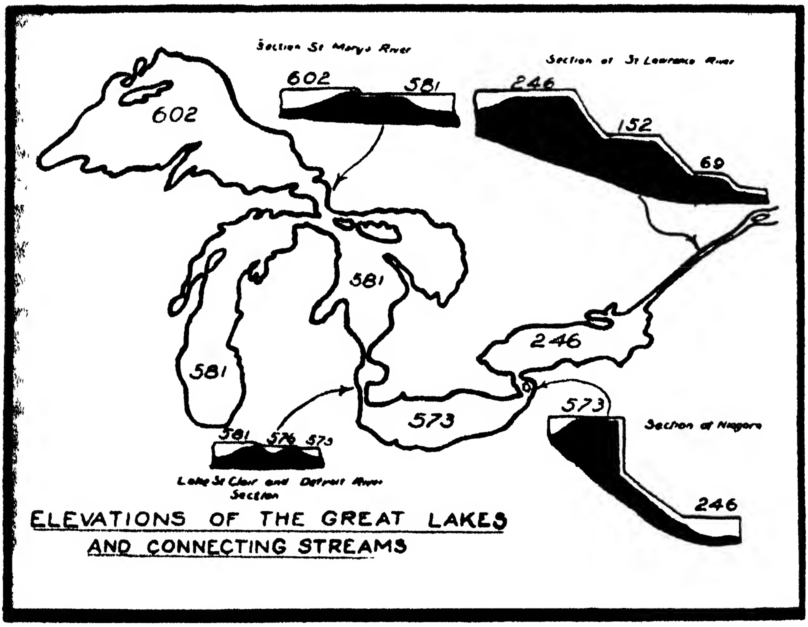

Fig. 1

drop from Lake Ontario to the ocean is 246 feet, which occurs mainly in three series of rapids between Lake Ontario and Montreal as shown here.

Any plan for the best use of the waters of the Great Lakes must be placed upon a consideration of the Chicago Sanitary District diversion problem, of the depth of water now available and that which will be needed later in the harbors of the Great Lakes and in channels connecting the Great Lakes, of the development of power at Niagara, and of the St. Lawrence project for improving navigation and developing more power.

The problem of securing the best use of the waters of the Great Lakes involves directly and strongly the interests of at least 18 states, where more than one half the population of the United States reside. Similarly it involves the interests of Southeastern Canada.

The Great Lakes and their connecting streams furnish the opportunity for the greatest development of inland water navigation possible anywhere in the world. In fact the inland navigation already developed on the Great Lakes and connecting streams is greater than anywhere else in the world. Yet the development of inland navigation on the Great Lakes is not nearly up to the possibilities.

More tons of freight pass Detroit in an open season of eight months than pass through both the Suez and Panama Canals in

three years[2] No set of canal locks anywhere in the world carries nearly so much traffic as the locks of Sault Ste Marie.

The Great Lakes and connecting streams, including the St. Lawrence River, are the most thoroughly studied bodies of water in the world. For example, careful continuous records of the elevations of the water surface of the Great Lakes have been secured from 1860 to date. The Niagara River has been gauged more than 800 times. The flow is known within 1 per cent. These unusually thorough studies enable one to plan improvements with confidence.

In order to secure the best use of the waters of the Great Lakes for the benefit of man six things should be done: (1) Carry out the St. Lawrence project; (2) Take out ten thousand cubic feet of water per second at Chicago, through the Drainage Canal, and use it well for sanitation purposes; (3) Build dams with movable parts at Buffalo and in the St. Lawrence River and use them wisely to regulate the levels of the Great Lakes; (4) Build a submerged dam at Niagara Falls to prevent the backward travel of the falls and the wasting of water where it does no good either for scenic purposes or for power; (5) Utilize the whole drop of 300 feet from Lake Erie to Lake Ontario for developing water power—as soon as is feasible; (6) Utilize the power opportunities on the St. Lawrence to the full, as rapidly as the market for the power can be developed.

What is the St. Lawrence project? What is its present status? In 1920 under the provisions of a treaty of 1909 between the United States and Canada, relating to the boundary waters, the International Joint Commission was asked "to investigate what further improvement of the St. Lawrence River between Montreal and Lake Ontario is necessary to make the river navigable for ocean-going vessels, together with the estimated cost thereof."

In 1921 the International Joint Commission, three men from the United States and three from Canada, reported back to the two countries. The main points of their report are as follows:

(a) That the Governments of the United States and Canada enter into an arrangement by way of treaty for a scheme of improvement between Montreal and Lake Ontario.

(b) That the proposed works between Montreal and Lake Ontario be based upon the report of the Engineering Board to the International Joint Commission, but that before any final decision is made that the Engineering Board report be referred back to an enlarged Engineering Board for a further more complete study. This Engineering Board report referred to certain specific dams and canals with locks for the improvement of navigation and certain power houses for the development of hydro-electric power.

[2] See the "Warren Report on Diversion of Water from the Great Lakes and Niagara River," p. 393.

(c) That the New Welland Ship Canal now under construction by the Canadian government be embodied in the scheme of improvement, and treated as a part thereof.

(d) That such navigation works as do not lie wholly within one country or are not capable of economic and efficient construction, maintenance and operation within one country, be maintained and operated by a board to be called the International Board, on which each country shall have equal representation, and that such navigation works as lie wholly within one country are to be maintained and operated by that country with the right of inspection by the International Board just referred to.

(e) That power works be built, installed and operated by and at the expense of the country in which they are located.

(f) That the cost of the navigation works be apportioned between the two countries on the basis of the benefits which each will receive from the new waterway; that the ratio of the benefits be determined in a certain way during the period ending five years after the completion of the works; and that the ratio shall be readjusted each five years, based upon the freight tonage of each country actually using the waterway during the previous five year period.

It is to be noted that this report of the International Joint Commission is primarily a suggested plan of procedure which should be incorporated in a treaty. It is also an approval of the general report of the engineering board with the suggestion that before actual construction is undertaken there should be further investigation.

The New Welland Canal, from Lake Erie to Lake Ontario, which is adopted as a part of the St. Lawrence project, is now under construction by the Canadian government. The total cost will be more than 50 million dollars. It includes locks with a depth of thirty feet and a canal with a depth of twenty-five feet which can easily be increased to thirty.[3]

The new construction on the St. Lawrence as reported by the engineering board includes thirty-three miles of canals with the necessary locks for navigating past the various rapids in the St. Lawrence—two large dams—and all the other miscellaneous construction necessary for the operation of the dams, locks and canals. It also includes the power houses and auxiliaries for developing 1,400,000 horse power. The navigation works, dams, etc., are to be so constructed as to make the ultimate development of an additional 2,700,000 horse power possible. It is not, however, proposed to make this expenditure to develop the 2,700,000 immediately, because it will take many years, possibly a generation, to develop the market for that amount of power. The construction is intended to keep step with the development of the market.

[3] Report of International Joint Commission on the St. Lawrence Waterway, 1922, p. 24.

At present the navigation along the St. Lawrence is limited to ships which can be operated in a depth of 14 feet. When this project as proposed is carried through the depth in all canals will be 25 feet and for an additional $17,000,000 it can at any time be increased to 30 feet. A depth of 25 feet will provide for the bulk of the ships now carrying freight on the ocean.

The total cost for the navigation works and the development of 1,400,000 horse power will be $250,000,000. The Panama Canal cost the United States about $400,000,000. As already stated more traffic now passes Detroit in each open season of eight months than goes through the Panama and Suez Canals combined, in three years.

The Panama Canal was built as a military necessity, to unite our Atlantic and Pacific fleets into one fighting unit. It passes a few commercial vessels each day from ocean to ocean—about 8 each way per day—serving the people of all the world. The Panama Canal is abundantly worth while.

For a much smaller cost—250 instead of 400 million—we may get an improved St. Lawrence-Great Lakes channel carrying several times as much ocean traffic as the Panama Canal and have power plants for developing 1,400,000 horse power thrown in. The benefits will be concentrated largely on 60 million of the people of the United States and Canada.

1,400,000 horse power at prevailing rates is worth $180,000,000 per year.[4] The total horse power developed at present in the United States from water is only about 9 million.[5] This one project would add 1/7 to this total development.

Electrical power can be transmitted with reasonable economy for about 300 miles. The 300 miles radius from the proposed development near the Long Sault rapids in the St. Lawrence includes all of New England and all of New York state and a still larger area on the Canadian side.

The present status of the matter is that the enlarged engineering board for further investigation has been provided for and a St. Lawrence Commission has been appointed by President Coolidge to meet with a similar commission to be appointed in Canada.

There is no doubt about the feasibility of the project, nor about the great benefits to be derived from it. As I understand it, the

[4] 1,400,000 horse power = 1,000,000 kilowatts. At 2 cents per kilowatt hour, one kilowatt year is worth (2c) (24) (365) = $180 per year and one million kilowatts is worth $180,000,000.

[5] *The Electrical Review*, June 5, 1920, p. 940, in an article entitled "Development of national water river resources," shows that in 1915 the U. S. Geological Survey estimate was 8,609,000 developed H. P. from water in the U. S. out of a potential maximum of 63,490,000 H. P.

questions to be immediately attacked are what part of the projects shall be taken up at once and what is the general plan which should be incorporated in the treaty?

The logic of the facts is so clear that the main question is how quickly and how successfully may the people of the United States and Canada be made to see the truth and how soon, therefore, will they eliminate their differences and get together in this work, which is the main part of the greatest opportunity now open for benefiting the peoples of the two countries.

The second of the six things which I stated should be done to secure the best use of the waters of the Great Lakes is to take out ten thousand cubic feet of water per second at Chicago through the drainage canal and use it well for sanitary purposes.

In the 90's Chicago secured permission to dig the drainage canal. It constructed the drainage canal in good faith. In so doing and in constructing the other works necessary to utilize the canal fully it has spent $100,000,000. It is now taking out of the lake nearly 10,000 cubic feet per second and has been doing so for years. It is using that water to dilute its sewage and to carry it away from Lake Michigan—away from the source from which Chicago draws its water supply. In doing so it has lowered the levels of Lake Michigan, Lake Huron and Lake Erie nearly half a foot, and has thereby caused damage to navigation. An attempt is now in progress, and has been for some time, to cut down the supply allowed to Chicago to but little more than 4,000 cubic feet per second.

Why should Chicago take out 10,000 cubic feet per second? It has made an investment of $100,000,000 in good faith on that basis, on the supposition that it will be allowed to continue to take out that amount continuously. The size of the drainage canal and the whole sewage system in connection with it is based on that assumed discharge.

The population of Chicago has already grown beyond the limit at which it is possible to dilute the sewage sufficiently—with 10,000 cubic feet of water per second—to keep it from being a nuisance. Some of the sewage, therefore, is now being treated before going into the drainage canal. The plans of the sanitary district provide for additional treatment plants on a program of construction reaching to 1945 which involves the expenditure of about 4 million per year (a total of 95 million). If the diversion at Chicago is cut below 10,000 cubic feet per second, say to 4,000 cubic feet per second, there will be an increase of millions per year in the necessary expenditure for sewage treatment—how many millions has never been carefully estimated so far as I know.

There is, however, a still more urgent reason for keeping the diversion up to 10,000 cubic feet per second. Even when 10,000 cubic feet per second are taken out the current in the Chicago River near its mouth reverses about once each year, either because of a sudden drop in the lake level—possibly as much as a foot—or because an excessively heavy rainfall occurs which reverses the flow If the diversion is only 4,000 cubic feet per second—with a slow current through the drainage canal—the Chicago River will be reversed on an average seven or eight times per year. At the time of each reversal there is a probability of the occurrence of typhoid and other intestinal diseases. If there were seven or eight reversals per year of the character that would occur with 4,000 cubic feet per second there is a certainty of occasional typhoid epidemics even with the best that can be done with dosing of the water with chlorine.

It is clear that Chicago should take out 10,000 cubic feet per second in order to keep its expenditures for additional sewage treatment plants within reasonable limits and in order to prevent the typhoid epidemics which must occur if there are frequent reversals of the current.

There may be some doubt as to the legal status of the matter. There can be no reasonable doubt as to the equity. Chicago secured in the 90's what was then believed to be the only permission required. It has constructed and used a one hundred-million dollar plant based upon the drainage canal and the use of 10,000 cubic feet per second. It has thereby saved many thousands of lives. There is no adequate substitute available in a reasonable time for the 10,000 cubic feet per second and the drainage canal. There is no possibility in any length of time of a substitute which will not cost much more than these two things. That statement is true even if Chicago pays for the regulating dams which have been proposed, and for which the sanitary district has offered to pay.

Chicago has lowered Lake Michigan, Lake Huron and Lake Erie by nearly half a foot. The most serious damage to navigation thereby produced has been the reduction in depth in the channel on the St. Clair flats above Detroit. For every tenth of a foot added to the depth there the largest vessels can each carry about 76 additional tons of freight at no extra cost. For the actual fleet of big ships operating past this point the additional revenue which they could so secure would be about $600,000 per year for each tenth of a foot added to the depth.[6] For two and one half to eight

[6] "The J. G. Warren Report on Diversion of Water from the Great Lakes and Niagara River," pp. 388–90.

million dollars two regulating dams could be built, one at Buffalo where the Niagara River leaves Lake Erie and one in the St. Lawrence (as a part of the St. Lawrence project). These dams properly operated would restore the depth lost by Chicago's diversion of 10,000 cubic feet per second—and more—would put the lakes at a higher level during the dry years than they would be in a state of nature, and would not put the lake levels above the danger limit in flood years.

The dam at Buffalo would raise Lake Erie first. The back water effect would then raise Lake Huron and Lake Michigan. The fall is less than nine feet from Lake Huron to Lake Erie—and nothing between Lake Michigan and Lake Huron. Clearly these two regulating dams should be built and operated. They would bring a benefit to navigation which would be a return over and above the cost of operation of 50 per cent. to 100 per cent. per year on the investment. The return would be at least three millions per year if the average depth over the St. Clair flats were increased by a half foot upon an average.

There is a strong sentiment in favor of preserving Niagara Falls as a great scenic asset to the United States. That sentiment is good. At present it prevents the use by the United States and Canada of much more than about one fourth of the water which goes down the Niagara River. Meanwhile Niagara Falls is slowly receding—wearing away. We should apply our sentiment sensibly. We should hold to the scenic value. We should prevent the wearing away and we should develop more power at Niagara. The value of the power now thrown away for the sake of the scenic value amounts to about $1 per minute for each person looking at the falls.

About one half of the water which now goes over the falls disappears in the angle of the Canadian falls,[7] where it contributes but little to the scenic value because it can not be clearly seen, and where it does much work in wearing away the falls. At the most serious point the edge of the falls is moving back about five feet per year. There is little wearing away at any other part of the falls. The scenic value at Niagara Falls comes mainly from the thin sheets of water running over the edge of the rocks at other places than this partially concealed notch—and from the rapidly moving water near the shores. We should build a submerged diversion dam to protect the notch in the Canadian falls, prevent the recession of the falls, divert the water in part to the other portions of the falls where it can be seen as it drops over and hold back a large amount of water which could then be used in the power plants.

[7] "Diversion," p. 275.

The falls would then be as beautiful, or more so, than they are now. They would be more permanent, and we could develop 50 millions of dollars worth of power per year at Niagara more than is now being developed.

You ordinarily think in connection with Niagara of the drop of 170 feet in the falls and forget that that is only about half of the total drop of 327 feet from Lake Erie to Lake Ontario. The present power plants are utilizing only the drop at and near the falls. Some of the present power plants are using that part very inefficiently. A Canadian plant is now being built which will use nearly the whole 300 feet of drop from Chippewa above the falls to Lake Ontario. Something corresponding to this should be done for all the water used for power. This scheme, combined with that of the submerged dam and with power plants rebuilt in some cases to secure high efficiency, would multiply the power development at Niagara by about four.

The sixth thing that I have suggested is that the additional 2,700,000 horse power postponed for future development, according to the present St. Lawrence project, should be developed as rapidly as the market for that power can be secured.

To summarize, to secure the best use of the waters of the Great Lakes for the benefit of man six things should be done: (1) carry out the St. Lawrence project, (2) take out 10,000 cubic feet per second at Chicago and use it well for sanitation, (3) build dams with movable parts at Buffalo and in the St. Lawrence River, and use them wisely to regulate the levels of the Great Lakes, (4) build a submerged dam at Niagara Falls to prevent the backward travel of the falls and the wasting of the water where it does no good, either for scenic purposes or for power, (5) utilize the full 300 foot drop from Lake Erie to Lake Ontario for developing water power instead of a half only, (6) utilize the power opportunities in the St. Lawrence to the full, as rapidly as the market for power can be developed.

Some miscellaneous comments are now in order. A large increase in the transportation facilities from the Great Lakes to the open Atlantic would do much to avoid future railroad congestion and embargoes. This is important.

The same additional transportation facilities as it is proposed to provide by the suggested improvements on the Great Lakes and St. Lawrence could not be secured by additional railroads and railroad terminals except at a very much higher cost.

Some ocean-going vessels can not navigate in a channel of 25 feet of depth. But the ships which carry most of the freight by

ocean can and would navigate such a channel. The freight of the world is not carried in ocean monsters. It is carried in ships of moderate size.

Locks are not a serious impediment to the progress of large vessels. The locks at the Sault and at Panama are a positive proof of this.

It has been a contention that Chicago should not take out water from Lake Michigan because it reduces the possible power development at Niagara. The reader will get a true view of this argument, if his sense of humor is in good order, when he considers that the diversion at Chicago, 10,000 cubic feet per second, is only 5 per cent. as large as the ordinary flow at Niagara, over 200,000 cubic feet per second.

The chance to use the waters of the Great Lakes in the best way for sanitation, navigation and power is the greatest opportunity to do a good service that is now open to the peoples of the United States and Canada. There are no serious uncertainties involved in the plans proposed. The time which elapses from now until that best use is made is a measure of the degree of intelligence of the American and Canadian peoples—and of the abilities of their governments.

The two nations, Canada and the United States, and the three interests, navigation, power and sanitation, should eliminate their differences and pull together in this work for the benefit of all.

POPULATION AND PROGRESS

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To appreciate the consequences of the expansion of populations, it is necessary to develop historical perspective. We may visualize the growth of humanity as beginning with small streams of population in the more favored regions of southern Asia and Europe. From the plains and river valleys first inhabited, the tide flowed over into adjacent areas until all the continents were occupied In some of the less favored regions populations remained quiescent without material increase or decrease. But in the more favored regions numbers grew rapidly, and poured out in floods of immigration and conquest over neighboring lands. The stress of the resulting competition and conflict weeded out the inferiors and promoted ability. This process of growth, expansion and the establishment of new levels of capacity has been repeated from prehistoric times to the present. We are in fact to-day in the later stages of the greatest population expansion that has ever occurred.

I. The Law of Population Increase

The increase of population is measured simply by the difference between the birth-rate and death-rate. Leaving out of account for the moment the question of migration, we may call attention to the forces which for long intervals of time have produced a relative balance between the two rates. It is obvious both from theory and experience that a virile population living under continuously favorable economic conditions will increase at a geometric rate; that is, it will double in a definite interval ranging from 25 to 50 years. The enormous potentialities of such a rate of increase are not apparent on the surface, and may be emphasized by the following calculation. If we assume the very low rate required to double a population in 100 years, that is, an average family of only two or three surviving normal children, then the six thousand years of human history would have been sufficient to give a present population of more than a billion times that now existing. Obviously the natural tendency to increase soon gives a surplus population in any favorable land area. When the surplus has become large, the lower classes are inevitably forced into poverty, even though agriculture may be intelligently managed and the distribution of wealth may be equitable. With poverty come vice and pestilence as nat-

ural consequences; and war is indirectly fostered by the same conditions. Eventually the death-rate approximately balances the birth-rate and the population becomes relatively stationary in numbers. This is the well-known theory of Malthus, which is admittedly true of earlier nations. Its applicability to present conditions may be deferred for later consideration.

It is important to recognize the social conditions growing out of the increase of numbers and determining the structure of typical ancient nations. Put in economic terms, the growing pressure of population in a hitherto uncrowded land area caused wages to fall, and land values and the cost of living to rise. Consequently, the position of the laborer and small land-owner was depressed, and the position of the large property holder was correspondingly enhanced. To be sure, in earlier times neither wages, products nor land values were measured at all accurately, but the conditions thus described in economic terms were apparent in the fact that life was cheap and the possession of good land was greatly desired. Out of such conditions arose land-holding aristocracies, defending their privileges with the sword, or relieving the pent-up energies of the nation in attacks upon neighboring peoples. Naturally the outcome of population pressure can hardly be described in a single phrase, since many circumstances have conspired to modify the particular event. Sometimes relief was temporarily found in migrations and trade, sometimes extended class struggles developed, sometimes militaristic aggression built up extensive empires. But whatever the details, eventually out of the ruck appeared established privileged orders on the one hand, and a dull and spiritless peasant or slave population on the other.

We may next briefly examine the conditions obtaining during a period of population growth. As may readily be seen, such a period is initiated by the opening of new territory or by some notable advance of invention, or by a combination of the two. Historical illustrations are the transition from barbaric to pastoral, and from pastoral to agricultural life, or the trade expansion of the ancient Greeks, the medieval Italians and the modern English. Such periods have usually brought strong democratizing tendencies. New methods of production and the growth of trade and cities have raised the status of the masses and offered opportunity to the capable. Hence the latent ability of the repressed lowly has made its influence felt, and a marked swing toward individualism and democracy has been experienced. It is perhaps not too much to say that economic expansion and democracy are causally interrelated.

Whenever a rising level of the industrial arts has thus allowed numbers to increase, it has generally been accompanied or followed by an overflow into neighboring territories through trade, colonization and conquest. This process is entirely natural, since progress brings both power and prestige, and makes backward areas appear by contrast to be sparsely settled. If the difference in culture is very great, the higher civilization in its expansion may sweep aside the lower civilization, just as the Indians were driven back before the advance of the American frontier. But if the difference is small, the process may be that of economic penetration, bringing with it usually a more or less acknowledged political dependence. Under earlier conditions such economic expansion merged with the militaristic aggressions already referred to, and even in modern times force has not been entirely absent.

While the conscience of the modern world has reacted against the cruder phases of the processes of expansion, it should be observed that progress has nevertheless been served thereby. Though attended with much waste and injustice, ancient imperialism such as that which Roman history recalls was a notable agent in the extension of civilization. Great areas of barbarism were turned from low production and tribal feuds into advanced production and the reign of law. And even when civilization fell, the incursions of barbarian tribes into the centers of a weakening culture brought infusions of new and virile blood, making possible a renewed advance. In spite of the wastes of such conflict, seldom was a civilization lost, while usually it was promoted and extended.

A bird's-eye view of the course of history with its short periods of advancing prosperity and its long centuries of relative stagnation raises the perplexing question why progress has not been more constant. Why has each advancing wave of culture been thrown back from its highest point of advance? No easy answer to this question is obtainable. Attention may, of course, be directed to this or that element of weakness in each social system. Sometimes the ruling class became simply exploiters rather than administrators. Sometimes natural resources were exhausted, or changes in climate diminished the fertility of the soil. But however unfavorable the environment may have been, the chief defect evidently lay in the dearth of men of ability and energy to cope with it. This defect was the consequence, so the biologists say, of a reversal of the workings of natural selection. Under cruder conditions society grew faster in the upper ranks, and the younger sons of the virile nobility, recruiting the ranks of the commoners, graded up the general level, while high death-rates weeded out the weaklings. But often in advanced

civilization this process has been reversed. The competition for preferment, the lure of luxury and the encroachments of vice have checked the increase of the more capable elements of the population, while the inferior have bred freely. Consequently, it is said, the level of ability has been lowered, the discipline of able leadership lost and civilization has fallen back to a lower level where natural selection was again brought into play.

II. The Modern Expansion of Civilization

Beginning approximately with the time of Columbus, the modern age is an example on a large scale of a dynamic tidal wave of progress, following in many particulars the precedents of the past. In the fourteenth and fifteenth centuries, there was little to indicate the vast proportions that this movement has assumed or the direction that it would take. Up to that time there had been little real advance of civilization since the Roman expansion; and some of the principal methods of production in agriculture, textiles and metals were but little beyond prehistoric antecedents. What is more, the level of European civilization was not materially above that found in the much greater areas and populations of Asia. In preceding centuries, Europe had with difficulty repelled the repeated attacks of the then higher civilization of the Mohammedans and had virtually failed in the exhaustive counter-attacks of the Crusades. The wealth and culture of the Indies and the Orient were still the magnets to which Europe was attracted. A Marco Polo of that era looking dispassionately upon the people and resources of the world would most likely have considered Asia the permanent center of world civilization. With what incredulity would he have greeted a prophecy of modern Europe or of the overshadowing New World of to-day! Yet it is the unprecedented geographic and cultural expansion of the white race that forms the theme of modern history and that has moulded the institutions and traditions of the modern age. Only recently has the great advance reached its farthermost barriers.

Looked at from the standpoint of territory, the white races have expanded from their obscure European position in medieval times to a point of world domination. According to Mr. Stoddard's estimates, of the fifty-three million square miles of habitable land on the globe, forty-seven million are either populated by the white race or are under white political control. In fact, about a quarter of the earth's surface and population is comprised within the British Empire alone. Of the 1,750 million inhabitants of the globe, 650 million, or 37 per cent., are white of European origin, while another sixty million, or 4 per cent., are white of non-European origin.

The next race in point of numbers is the yellow with 510 million, or 29 per cent. The brown race comes third with a population of 420 million, or 24 per cent.; while the black race comes last with a population of 110 million, or about 6 per cent. While Asia on account of its great size still has a bare majority of the world's population, it has utterly lost its place in respect to culture and progress.

The position gained by the white race is rendered more secure by the immense resources of the new lands which it has acquired. The greatest areas of arable land outside the tropics are Europe, North America and southern and eastern Asia. If we include smaller areas in South America, Africa and Australia, the arable land of the white race will be found to surpass that of the yellow and brown races combined by nearly two to one When the comparison is made in terms of the physical basis of industrial power the contrast is still more striking, since the United States alone has probably half of the world's coal and iron reserves, together with immense resources in other minerals. In respect to climate, also, the white race possesses a great advantage. The climatic conditions of Europe and the United States are preeminently of the kind that awakens and sustains human energies.

And not only has the white race gained a dominant world position, but its relative power increases from year to year. Professor East estimates that the white race of European origin is increasing on a prewar basis at an average rate of nearly eight million a year, which is about 60 per cent. of the total increase of the world's population. Its nearest competitor, the yellow race, is increasing by only one and one half million a year. To put it another way, the white race is doubling in a period of 58 years, while the yellow race at its present rate of increase requires 232 years to double. The black race is increasing a little faster than the yellow, but its numbers are relatively so small that its growth is insignificant. Added to the ascendancy of territory and numbers, the white race has acquired such an enormous lead in scientific and industrial development, in social organization and in the general education of its masses that its power is greatly multiplied. Thus the period of European expansion which began with Columbus and which swelled to such immense proportions in the nineteenth century has already carried the white race to the point of secure world domination in respect to power and prestige, and is still carrying it forward with a momentum that far surpasses the rate of progress of the other races of the world. Nor has the World War changed the situation materially, the rates of increase in the more advanced countries having reverted to prewar figures almost immediately after the close of the conflict.

The interracial comparisons which we have just made seem to indicate that the so-called yellow peril is an exaggeration and that, in fact, the backward races might more logically speak of a white peril. There is, nevertheless, something to be said in regard to the increasing resistance which the backward races are beginning to offer to white exploitation. This increasing resistance is not, however, a reaction to wrongs that have been suffered at the hands of the white race, as some would have us believe. In spite of many regrettable incidents, white expansion has been more beneficent to the populations it has overrun than has ever been true of corresponding movements before. Except in a few minor instances, it has conferred on the backward peoples far more than it has taken from them. On account of its great cultural achievements, it has everywhere brought industrial improvement, suppression of disease, higher knowledge and superior laws and ethics. If there is a yellow peril or race peril at all, it is the result of the increasing ambition and power which the new civilization has stimulated in the backward races.

A brief survey of the situation in the Orient will be sufficient to set forth the case. The population status of Asia has historically been established by a great overcrowding which has balanced an exceedingly high death-rate against a correspondingly high birth-rate. With the coming of modern methods of sanitation and the improvement in means of production and transportation, the death-rate is being temporarily lowered. But, on the other hand, the birth-rate is entrenched in ancient customs and religious beliefs which give way but slowly before the advance of the new civilization. As a consequence, population increases so quickly that little benefit is derived from improvements in production such as have been brought about by British engineers in Egypt and India and by the newly educated leadership of Japan. India, for example, has increased from 178 million to 332 million, or 30 per cent., in half a century. This population is about six times as dense as that of the United States and is almost wholly agricultural. As a consequence of such overcrowded numbers, the rate of increase is now checked at less than one tenth that prevailing in the United States and Europe, although the birth-rate is twice as high. At the same time the mass of the population is inevitably held down to standards of living that are incredibly low from our point of view, but which can never be raised as long as the present population tendency lasts. Of all the Orient Japan has experienced the greatest benefit from the influence of western civilization. As a result its overcrowded population has already shown a rate of increase equal to that of Europe, although

the per capita income is less than 10 per cent. of that of the United States.

Oriental peoples, therefore, numbering about half of the population of the globe, are repressed by overcrowding to a degree that we can hardly comprehend, and the benefits of modern scientific production and sanitation mean very little to them except by way of awakening ambitions that only a few can attain. It is but natural, therefore, that they should look with envy on the sparsely populated areas of Australia and America and consider the white man's policy of exclusion unfair. Wherever they can find a foothold they will do so, and with their low standards and habits of industry will displace other populations. Potentially their hundreds of millions might become billions if land were available, but now that the white world has put up the immigration bars it is not available. Their own lands can not be made the basis of a much greater food supply than at present. While they may find room for some expansion into Northern Asia, they are not at all likely to increase to a point where they could menace the white race in direct conflict, though they may be an important factor as an ally to one or another of the competing elements of the white race. The principal cleavages of the future will doubtless still be divergent white civilizations against each other, as in the past. A Teutonic-Slavic alliance, for example, might find Oriental allies. But the cleavages of the Orient are as deep as those of the Occident, and a united East is an improbability. The yellow peril, in as far as it exists, is chiefly the menace to high standards that is inherent in low standards, a menace which is not limited to alien races. It holds no alarming threat to the white world except under the now abandoned policy of unrestricted immigration.

III. Diminishing Returns

It is popularly assumed that the industrial progress which has characterized the nineteenth century will continue indefinitely and that therefore social standards will continue to advance. Many students of world affairs, however, hold a contrary view. Briefly stated, they consider that the present era of progress has resulted from the vast new lands that have been made available, and that the relative disappearance of poverty and the rise of democracy are merely incidents of this expansion. They assume, therefore, that with the inevitable return of population pressure, labor will be cheapened and society will again revert to mass poverty, militarism and authoritative government by privileged classes. That is, they assume the Malthusian theory to be strictly applicable to the case. And when the pertinent data are examined it will be found that this view is at least worthy of consideration. We shall then briefly

review the arguments usually cited in support of the theory that population pressure and its attendant social conditions are returning

At first thought, the history of invention and business progress during the last century or two certainly gives the impression that permanent progress is now assured. During almost all this period of time right down to the present, wealth and income have been increasing faster than population, at least in the more advanced portions of the world. It would seem, therefore, that in view of the possible further achievements of science no shortage of production is in sight. The optimist points to the so-called miracles of science: to power machinery, to the conquest of distance and finally to the achievements of scientific agriculture. In view of increased wealth and the abundance of food he laughs at the possibility of coming scarcity.

But on further consideration much of this exuberant optimism will be found to be mere rhetoric. The fact is that the achievements of science are not primarily of the sort as yet that will alleviate the increasing demand for food in overcrowded areas. What science has done is to render possible the extensive cultivation of new lands rather than to increase materially the production per acre. As a result, the populations of Europe are to-day in a large measure dependent upon newer regions for the food supplies which they purchase with the products of their factories. It is true that European agriculture has also made great advances because of proximity to the primary markets. But in spite of this progress, the United Kingdom depends upon the outside world for over 50 per cent. of its food, while Germany, France, Belgium, Italy and Holland, in the order named, are also dependent upon food importations. The same may be said of Sweden and Norway, although these countries could be practically self-supporting if necessary.

The chief sources upon which Europe depends for its food supply are, on a prewar basis, Russia, the United States, Canada, Argentina, India and Australia. As long as these countries continue to export large surpluses of food and to import manufactured products, Europe can maintain its present population. But in the main the food-producing countries just mentioned are rapidly progressing to a point where they will produce much of their own manufactures and consume the bulk of their food products. This is particularly the case with the United States, where the exportation of foodstuffs is now overshadowed by the exportation of manufactures and manufacturing materials, the proportion in 1921 being 260 per cent. The United States is, therefore, more of a manufacturing rival of Europe than an agricultural support. Australia and Canada and to a lesser extent Argentina, with their rapid increase

in population, bid fair to approach the same situation within a generation or two. Russia will eventually move in the same direction and will have an enormous population of its own to feed. Even India may some day gain its economic independence or become tributary to Asiatic powers.

But it will be argued that the increasing demand will be met by a more intensive agriculture and a consequent greatly increased yield per acre. There is, doubtless, considerable room for improvement in this respect but not as much as is usually assumed. The possibility is confused by viewing it in the light of the increased agricultural production per laborer which has resulted from the use of cheap lands. But the fact that we have increased agricultural production per laborer tenfold has little bearing upon the problem. This gain having been dependent upon new and cheap land is necessarily transient. Science has not yet demonstrated that it can increase the yield per acre in anything like the degree that it has increased wealth as a whole. The United States, for example, with all its use of agricultural machinery, produces little more than two thirds of the average yield that Japan gets with its semi-medieval methods. Even Belgium, which holds the world's record for intensive scientific agriculture, can barely double our record, and this only with the aid of several times our outlay of labor per acre Such a comparison clearly indicates that intensive agriculture, even with the use of the most scientific methods, can not increase food proportionate to the recent rate of increase in population. And production thus increased, though it will bring larger returns to capital, will necessarily mean lower incomes and standards for the masses who live chiefly by their toil. Diminishing returns and cheapening labor inevitably go together.

In view of the world's agricultural outlook, it may plausibly be argued that population pressure is already in evidence. Thompson estimates that the close of the nineteenth century brought the beginnings of diminishing returns to American agriculture; that is, the former lowering costs of expanding agricultural production began to give way to rising costs. This, of course, would naturally be anticipated with the disappearance of high grade free land. It is also argued that the disappearance of the frontier has already made itself felt upon the status of the laborer. Wage data in the United States do in fact show a cessation of the former rapid rise in the purchasing power of wages, there having been little or no permanent increase from about nineteen hundred up to the World War. As to Europe, it is said that the condition of the masses has in recent decades shown a more unfavorable trend except as it has been relieved by the favors of social legislation. It has also been pointed

out that the widespread popular discontent evidenced by radical agitation has in turn driven the aristocracies of Europe to make extraordinary efforts for the capture of foreign markets. Under such circumstances, the militaristic attitude has naturally been fostered.

A significant change which is attending the approach of overcrowding is a gradual lowering of the birth-rate, although this change has not thus far produced conspicuous results on account of a similar decline in the death-rate. Biologists have recently been pointing out that the decline of the birth-rate is differential as between superior and inferior stocks and that the numbers of the incapable threaten to swamp the more capable. Many followers of Malthus are inclined, however, to look upon the change in a more favorable light. They consider that the checking of increase is desirable, and while they deplore the present dysgenic trend, they regard it as temporary. In their view it is incidental to the extreme competition for higher social rank that goes on in an expanding civilization—a competition which generally results in late marriages and small families among those who are achieving success. But it is pointed out that as wealth becomes hereditary with those stocks which have proved their worth, family pride is developed and the size of the family tends to become normal again. Though the birth-rate among the established wealthier classes may remain a little below the general average it will doubtless be compensated for by a low death-rate. It is also argued that the present rapid increase of incompetents can not go much further since it must necessarily be checked by increasing poverty and hardship, unless remedied by more positive measures And though the future may see a large class of inferior and low-paid workers, we are reminded that such a population can profitably be used in the routine labor of modern machine production. Hence the Malthusian is likely to consider that, if prospective wars are not too disastrous, society will at length find stability under the new conditions. The upper classes, being the descendants of those who have proved their worth in the long competitive struggle of the epoch of expansion, may be counted on to rule with wisdom, while the inferior multitudes, after they have become accustomed to low standards and obedience, will find the peace and order of the new era advantageous.

IV. The Outlook

How shall we evaluate the outlook that the modern Malthusian presents? Is it simply the product of the exaggerated ideas and fears that have come with the disillusionment of the World War, or is it a well-founded forecast of the trend of world affairs?

The opinion of the writer is that as far as any definite prediction goes, the Malthusian theory will prove to be misleading. Predicting the future by the past is too mechanical a method of prophecy to be minutely reliable. While it is true that physical causes will produce uniform physical results, it is not true that human reactions to natural conditions will be the same to-day as in the past. It might be predicted, for example, on the basis of ancient experience that modern Europe would pass through a cycle of wars, finding equilibrium at length in the unquestioned supremacy of some military power. And it must be admitted that the recent war and present conditions suggest altogether too strongly the possibility of such a solution. But, on the other hand, new ideals and aspirations have been awakened in the modern world which make such an outcome improbable. It was the moral imponderables in the recent war which finally determined the course of events. However impracticable idealism may be, and however much of illusion it may cherish, it is nevertheless a force to be reckoned with. Hence the easy conclusion that the coming pressure of population will throw the world back to older types of aristocracies is very questionable. Some tempering of the extremes and crudities of democracy there may be, but the precise course of events will very likely proceed upon lines which can not now be anticipated, because the advance of science will bring new instrumentalities into play.

Even as it stands to-day, there are several forces at work which will serve to counteract the results of natural increase. One of these in particular many followers of Malthus have strongly emphasized; namely, the artificial restriction of population. Unfortunately, their propaganda has been largely responsible for the dysgenic effects already alluded to. Furthermore, it arouses a strong moral opposition and is especially repugnant to the more virile populations who aggressively seek to further their class or national interests. Hence it is not at all likely to prove the cure-all for social ills that the Neo-Malthusian thinks. Nevertheless, it remains an influence tending to relieve the stress of overpopulation and might possibly be given a eugenic trend.

Mention may also be made of another line of attack. The advance of psychology has made it possible to distinguish and in some degree to measure the mental incapacities which result in poverty and crime. The development of institutions for the pauper and the criminal has already shown that it is quite possible to deal with various classes of incompetents both humanely and economically. In well-managed institutions they are far happier and more productive than if allowed their freedom. A considerable expansion, therefore, of institutional care for these classes would be advantageous from the standpoints of both humanity and natural selection.

A further factor in relieving the effects of overpopulation is progress in the production of food. While it is quite probable that such progress must continue to take place under conditions of decreasing returns and lowering wage trends, yet the possibilities in sight are considerable and there is some chance that science will discover novel and more efficient methods. It has been estimated that on the basis of present knowledge food production in the United States may be increased 50 per cent. or more by bringing new lands under cultivation; and as we have already seen, comparisons with other countries indicate that the yield per acre may be nearly doubled. In the overcrowded countries of Europe and Asia some increase of lesser degree will doubtless be attained. In the tropics of South America and Africa the supervision of the white race may yield a considerable increase. Something may also be said for the potential productivity of the "Friendly Arctic" and for a possible increase in the supply of sea foods. Progress in these various directions will at least serve to put off the evil day that the Malthusian predicts, though not without the disadvantages of diminishing returns.

Nevertheless, after all due allowance is made for exaggerations and omissions, it remains true that the Malthusian is calling upon us to face the fundamental facts of a new age. There is no escaping the conclusion that the era of rapid and easy expansion is drawing to a close. And it must also be evident to the student of history that the world will be profoundly affected by the change. The conditions that have fostered the age of democracy in both its economic and political aspects are disappearing, and the conditions which in past ages have made for mass-poverty, conflict and aristocracy are returning. While this does not prove that the world will revert to its evil past, it does emphasize the necessity of an informed and enlightened statesmanship. Only an application of scientific methods to social management gives promise of escape.

We may observe, however, that for reasons already stated it is Europe rather than America which must bear the brunt of the renewed population pressure. Because of our development under totally different conditions we are wholly unprepared to understand the situation of the European peoples, either by way of sympathizing with them in their difficulties, or of appreciating the dangers arising from their militaristic tendencies. With us the acquisition of foreign markets is a relatively unimportant incident affecting normally not much more than 10 per cent. of our trade. It would be quite possible, in fact, for us to reduce this trade to a bare minimum and still to be prosperous. Hence we look upon the aggressive commercialism of Europe, and the imperialism that goes with it, as

simply evidences of degenerate greed, never stopping to think that the clamor for markets is merely the obverse side of the insistent demand for food on the part of an ever-growing population. It is, of course, with the proceeds of the sale of their manufactures that the industrial nations of Europe buy their food imports. If markets fail, unemployment and starvation become inevitable. What, therefore, must be the attitude of the governing classes of Europe as they view the rising tide of world competition in manufacturing and in the appropriation of the food surplus. Unless they can succeed in finding raw materials for their manufactures and markets for their products they are in real danger of popular disorders and even of anarchistic uprisings. Yet we persist in viewing their aggressive policies as being inspired merely by a deliberate malice. It is assumed that if kings and diplomats could be prevented from misleading a peace-loving and industrious people, all would be well. That the simple peasant, rearing his large family in the overcrowded regions of Europe, may possibly be more instrumental in producing conflict than diplomats and militarists together seems incredible to us. Yet in fact the turmoil of Europe arises chiefly from the difficulty of feeding the increasing populations and of meeting their insistent demands for higher standards of living. And this turmoil is likely to continue until an adjustment to the new world situation is reached.

In our own more favored land, however, the change to the new conditions is coming very gradually, and no serious consequences need be anticipated for many years to come. It is true, as we have seen, that the rapid rise in wages which characterized the period of an expanding frontier came to a close about 1900 when diminishing returns in agriculture were first in evidence. But, relatively speaking, our population is still a sparse one, being little more than a tenth as crowded as are the industrial peoples of Europe. Besides, with its higher standards of living, it is already adjusting itself to the new conditions, as is evidenced by the decline in the average size of the family from 5.6 in 1850 to 4.3 in 1920, and by a parallel fall in the decennial rate of natural increase from 25 to 11 per cent. Our new policy of immigration restriction is also materially helping to postpone the day of surplus population, and has already helped to give wages a renewed upward trend. Hence, though land values may be expected to continue their rise after the period of postwar readjustment is past, no rapid cheapening of labor is to be expected. The conditions, therefore, which are becoming so apparent in Europe, by which property and privilege are elevated, while the value of human life is depressed, will come upon us slowly if at all.

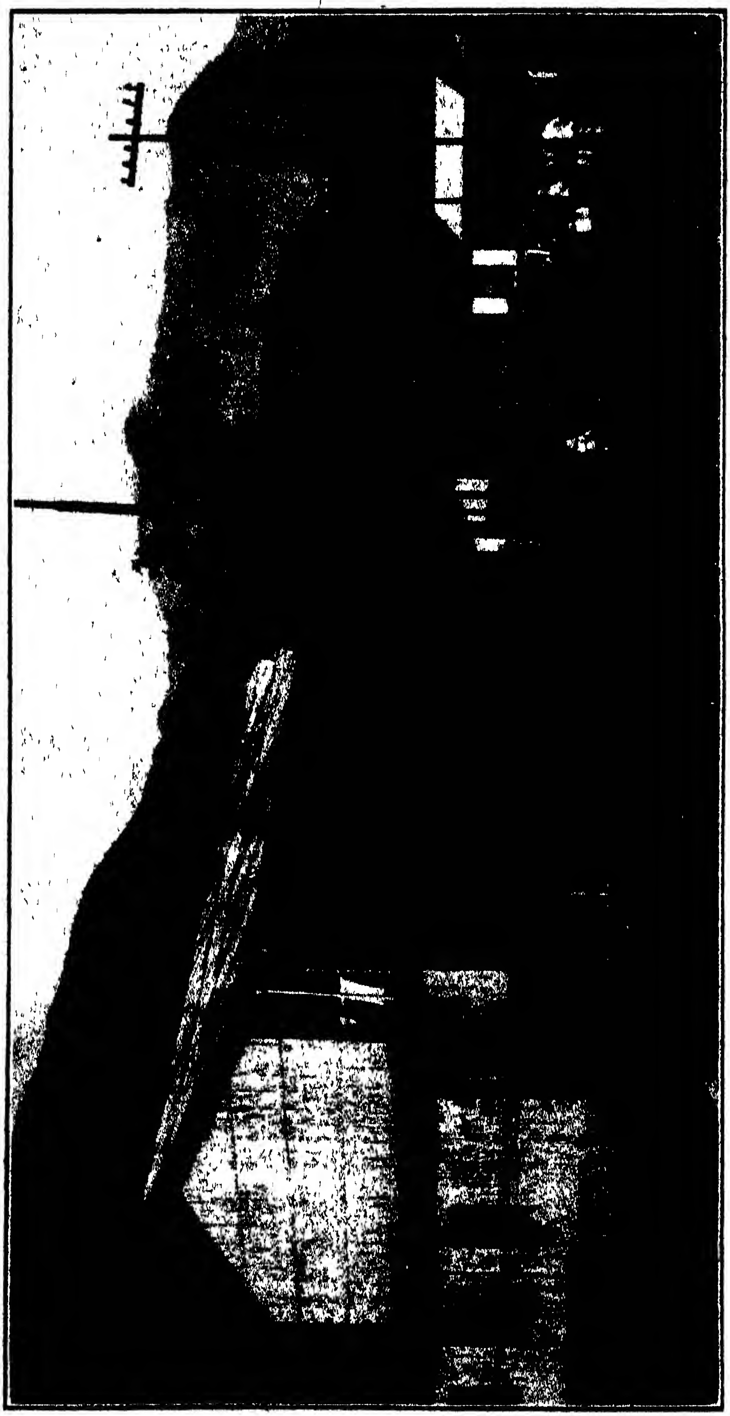
BOTANIZING IN ECUADOR

By Dr. A. S. HITCHCOCK
U. S. DEPARTMENT OF AGRICULTURE

IN my study of the grasses I have found it necessary to do a large amount of field work in order that I may really know the plants and their habits. In recent years my attention has been turned to South America, partly because of my trip to British Guiana in 1919 and partly because of the great influx of plants from that continent most of the grasses of which were submitted to me for identification. The Gray Herbarium, the New York Botanical Garden and the U. S. National Herbarium have adopted a policy of cooperation in the study of the plants of northern South America. In accord with this policy, I made arrangements to visit Ecuador for the purpose of making a general collection of plants in three sets for the three institutions mentioned. In order to take advantage of this situation, I was authorized to visit Peru and Bolivia, where I devoted my attention in the main to a study of the grasses. The three countries included the region of the central Andes, and the results of the study of the grasses here added to that given to the grasses of Colombia and Venezuela collected by Dr. Pennell and his assistants in the former, and by Pittier, Jahn and others, in the latter country, would give a fair idea of the grass flora of the Andes within the tropics.

So it came about that my wife and I started from New York on May 25, 1923, on a Panama railroad steamer for Cristóbal. We landed for a few hours at Port au Prince on the way, and arrived in the Canal Zone on June 2, where we waited until June 10 for a boat to Guayaquil, the *Huallaga* of the Peruvian line. A few grasses were collected at Buenaventura, where a stop of a few hours was made, and then we proceeded to Guayaquil, landing on June 16.

Landing from a steamer in a strange country is always a nerve-racking process—there is the health officer, the passport examination, the custom house, the landing of the baggage, the unfamiliar money and, since landing was by lighter and launch, the bargaining for passage ashore with greedy cargadores, a dozen of them all pushing and talking and gesticulating at once. I was greatly relieved when a man came forward with a letter from Mr. James Rorer, the well-known mycologist, whom I had met in Trinidad. The bearer would look after my things from steamer to hotel, including custom house. Oh joy! what relief! And he did it, too,



House at Huigra

The side walls are sheathed with bamboo boards, a common building material in western Ecuador. The stems are split down one side and flattened out.

and the price was reasonable. Fortunately I had a letter from the Ecuadorean minister in Washington to the custom officials in Guayaquil which smoothed things wonderfully. We had nine pieces of heavy baggage, including two large boxes of collecting paper with the tops screwed on. The custom house was hot and steamy. "These boxes contain paper for my plants, shall I open them?" "Oh no, Señor, that is all right." The pieces are checked and off we go. Mr. Rorer himself could not be there, as he was on his plantation in the interior.

For a few days I was busy getting in touch with officials and others who might be able to help me, making connections, as it is called. Dr. F. W. Goding, our very kindly and efficient consul-

A Fine Summer Residence at Huigra
The walls are of two crossed layers of bamboo board covered with stucco.

general, was of inestimable service. The governor of the province gave me a letter, in Spanish, to officials, a letter of especial value in remote regions where a plant-digging idiot would be under grave suspicion.

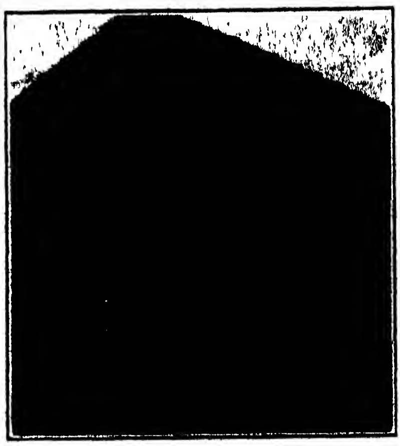
While wandering along the river front in the city, I saw a grass growing in the tidal mud which proved to be a little known species described by Kunth from the collections of Humboldt and Bonpland at the time these naturalists visited Guayaquil at the beginning of the last century. The name, *Eriochloa polystachya,* had been applied to other species in the United States and tropical

A HOUSE UNDER CONSTRUCTION, CUENCA

The poles are tied to the frame with agave fiber. The cultivated fields are carried far up on the mountain side. An agave hedge back of the house. Four eucalyptus trees in background.

America, none of which quite agreed with the original description and plate. Here was the real thing—and from the type locality—another puzzle solved!

While at Guayaquil, I had the privilege of collecting at several places on the coastal plain: Through the courtesy of Mr Orr, geologist, and Mr. Clark, superintendent, at an oil camp toward Salinas; at the plantation of Mr. Cleveland at Teresita, a very wet belt close to the mountains; at the plantation of Mr. Rorer, who is raising cacao, coffee and bananas; at the sugar plantation in charge of Sr. Perez Conto, near Milagro. At the last place, Mr. Meigs, the manager, and Mr. Platts, the chemist, are Americans, the latter a mate of my daughter at the University of Michigan (so narrow is the world!).



FRAMEWORK OF HOUSE

It is partly filled in with mud. Later the walls will be plastered.

FRAME WORK OF HOUSE

The small cross pieces are carrizo (Arundo donax).

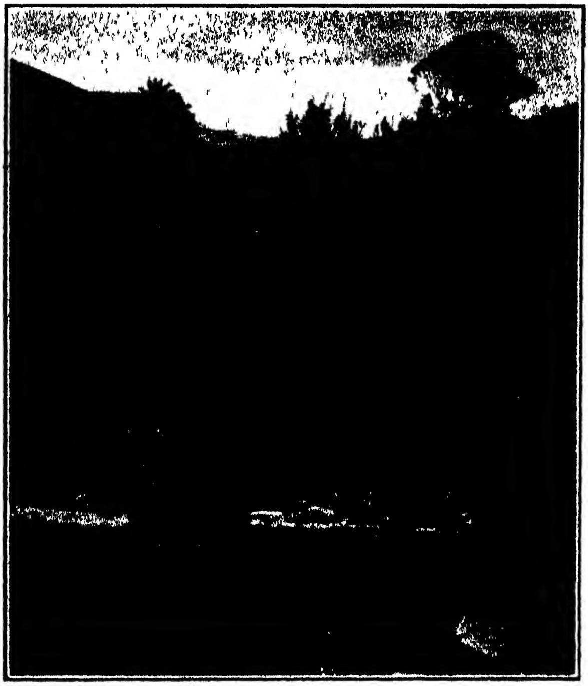
Guayaquil is warm, but not so warm as Panama. The whole coast of South America south of Colombia is kept comparatively cool by the Humboldt current coming up the coast from the Antarctic regions. The temperature at Guayaquil rarely goes above 85° F. Formerly this city was a hotbed of yellow fever and other tropical diseases, but is now clean and safe.

AN ADOBE HUT

With plastered walls and grass-thatched roof. Common type in the Sierra. The trees are eucalyptus.

For a part of the time we had our headquarters at Huigra, in the mountains on the railroad to Quito. Here at an altitude of 4,000 feet the climate is very fine. The Guayaquil and Quito railroad crosses the coastal plain and then rises laboriously up through a steep valley to the Sierra, getting up to 10,000 feet in a few miles, and then goes down into a high valley and passengers stay over night at Riobamba. The road was a difficult piece of engineering. Up through this valley the grade is often 3 to 5 per cent. and reaches a maximum of 5.5 per cent. The mighty engine did much chugging to get its little train of four cars up these grades. The

HOTEL AT MALCHINGUI



CORRAL AND TOILET ROOM OF HOTEL AT LOJA
Note the open well in right foreground. All water should be boiled before drinking.

second day is spent going from Riobamba to Quito, over successive passes and valleys past mighty Chimborazo to Ambato and Latacunga, past superb and graceful Cotopaxi into the bowl near Pichincha, where is located the capital at 9,500 feet altitude, a rather cold place because of its height.

Arrangements were now made for a trip to Tulcán on the Colombian border. I was very fortunate in obtaining for a companion Mr. J. R. McWilliam, a young American living in Quito, a Seventh-Day Adventist missionary. He speaks Spanish and is familiar with the country and its customs. Still more important, he is a gentleman of high character and proved a helpful friend as well as an efficient aid. Mr. McWilliam accompanied me on my other trips in Ecuador. He attended to the business details of the expedition and served as a buffer between me and extortionate guides and mule-owners. Those who travel in out-of-the-way places will agree with me that much of one's energy is used in getting from place to place and the unescapable details are such a severe tax on one's time and patience that little of either is left for scientific work.

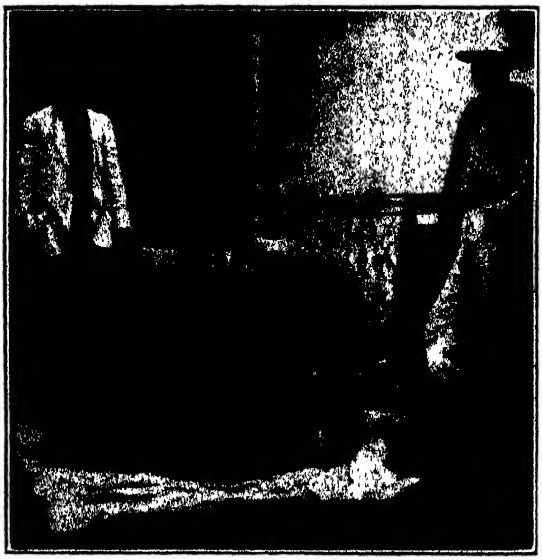
The limiting factor in travel by mule is forage for the animals. The animals are given no grain, but are fed night and morning, and also noon when possible, some kind of cut green forage, alfalfa when available, otherwise, corn stalks, sugar cane, barley, bamboo, gamalote (*Axonopus scoparius*), or even wild grass or weeds. Necessity for obtaining forage compels stops for the night in the cultivated valleys, and therefore at the inns of the towns or huts of the Indians The botanical specimens of interest are obtained mostly on the ridges and passes between the valleys. If night threatened to overtake us in good collecting ground we were obliged to hurry on to the next place where our animals could be fed.

The first night out of Quito we stopped at a ranch which was accustomed to supply shelter and forage to traveling caravans. I had a saddle that I had brought from home, and I carried a folding cot with a pad or thin mattress and blankets. We were assigned to a room without furniture, water, light or conveniences of any sort. We were able to obtain hot water, the rest of the meal we supplied ourselves. One must travel with bed, supplementary food, candles and simple utensils. Fleas, lice and bedbugs are likely to be encountered and care must be taken to remain free from attack.

The day's travel out of Tulcán will illustrate the troubles of a plant collector. We arose at 2:50 in order to have an early start and get out of the valley to good collecting soon after daylight.

A WAYSIDE INN

Our caravan ready to start. Mr. McWilliam on mule in center.

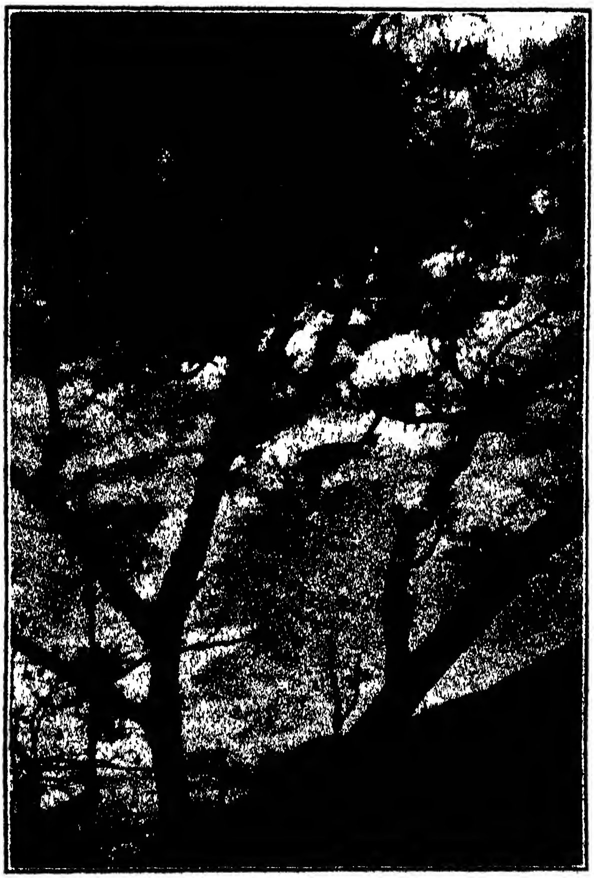


A Bale of Unfinished Panama Hats
They are being wrapped for shipment at Cuenca.

I was suffering from a rather light case of diarrhea and was confining my diet to boiled milk. I drank a bowl of milk for breakfast and filled my canteen with milk. We were able to start about five o'clock and then proceeded through the uninteresting valley for an hour. Our destination was La Rinconada, a large ranch on the way to Ibarra where we had stopped on the way north. Collections were made, partly in the rain for about two hours and then we hurried on for the páramo that we had passed through on the way over. A páramo is a ridge, slope, or plateau above tree line and has a characteristic flora. It is a bleak place often with a cold wind sweeping over it, often with squalls of rain or even sleet. In the afternoon we arrived on this páramo and hurriedly collected as long as we dared spare the time and yet get to the ranch. Here we saw a wonderful forest of frailejones, a treelike composite that forms extensive forests for miles over some of the hills of the páramo. The trunks are mostly 6 to 8 feet high but may be as much as 15 feet. The collecting here was so good that we remained longer than we ought. The road we were following was not the main highway between Tulcán and Ibarra but a fainter road to the La Rinconada Ranch. Darkness soon overtook us, and we had to trust to the mules to follow the path. As they were not familiar with the region there was danger of their following the wrong road and this is what they did on the ranch itself. About ten o'clock,

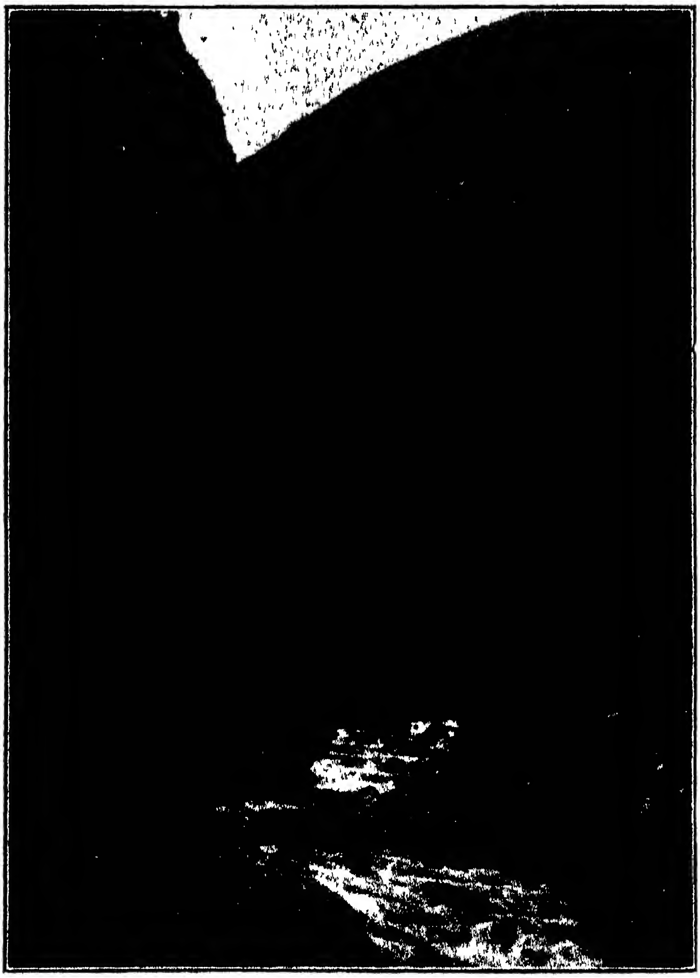
in darkness so dense that we could not see the heads of our own mules, we found ourselves ascending a very steep hill, so steep that our pack animal stumbled and fell. The animal was down on the slope with the pack slipped under its belly. Here was a disaster of major importance. Removing a pack from a frightened mule in the dark is ticklish business. Passing over troublesome details we finally reached the ranch house amid the barking of about a thousand dogs. Even with this bedlam, the servants were unable to awake the owner and we put up our beds in the kitchen. I had had nothing to eat since 4 A. M. except a quart of boiled milk in my canteen. We were given a bowl of hot milk and finally retired at 1:50 A. M., a day of 23 hours, much of it in the saddle. This is a sample of the vicissitudes of the traveler in remote regions.

The next trip was through southern Ecuador. We went by



TILLANDSIA

A tree with several species of Tillandsia (wild pines or bromeliads), Southwestern Ecuador. Epiphytes are very abundant in this region.

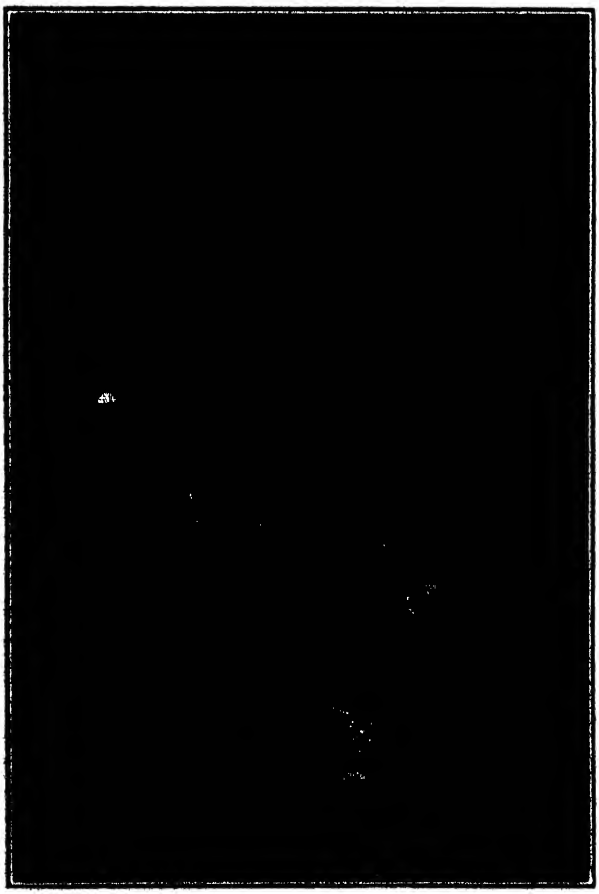


A MOUNTAIN GORGE NEAR OÑA.

boat to Santa Rosa and with mules by stages to Loja, Cuenca and Huigra. The method of travel was to hire the animals and a driver for each stage, two pack mules for the outfit and three saddle mules for McWilliam, the muleteer and myself. The muleteer was responsible for all the animals, looked after the loading, feeding, saddling and anything else there was to do, and was also guide and interpreter with Indians who could not speak Spanish. Payment was made in advance to the responsible party from whom the mules were hired, the price averaging 5 sucres each per day for the mules and the man. At this time the sucre was worth about twenty cents. At no time during my entire stay in Ecuador were

the mules brought at the hour agreed upon—we were in a mañana country.

The first stage, two days, took us to the gold mine at Portovelo near Zaruma. Here we were the guests of the company by courtesy of Mr. Tweedy, the manager, and Mr. Kellogg, the superintendent. It is worthy of record that we had here good American griddle cakes and syrup. The second stage, three days, brought us to Loja, where we spent one day drying plants. In five days more, including one day's rest on the Sabbath (Saturday, Mr. McWilliam being a Seventh-Day Adventist) at Oña, we reached Cuenca, the third city of Ecuador. This is one of the centers of the Panama-hat industry, almost the entire population weaving the hats. The palm is a native of the coastal region, but the young leaves are brought up to the highlands to be made into hats. The city is much isolated as its nearest railroad connection is at Huigra.

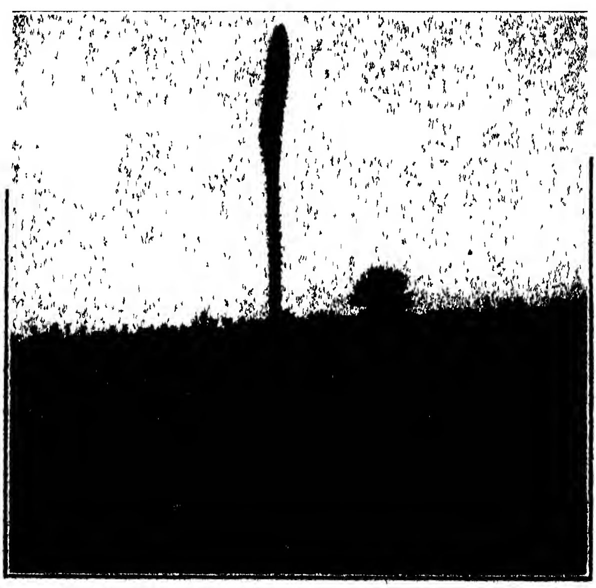


BRIDGE ACROSS GORGE AT BAÑOS.

FRAILEJONES
A forest of frailejones (Culcitium sp.) páramo of Northern Ecuador.

Much of the traffic of Loja is out by way of Paita in northern Peru. Two days' travel from Cuenca brought us to Huigra

The collecting was good on the trip but as usual the interesting plants were found on the wet ridges between the valleys or on the páramos. Twice we spent the night in the mountains in order to get sufficient time for collecting. The forage question is troublesome, as it is not easy to provide feed for the animals. If wild grass is available the animals must graze during the night when they ought to be resting. In wooded regions there is no suitable grazing.



AN AGAVE-LIKE PLANT IN A FOREST OF FRAILEJONES

The kindliness of the natives is illustrated by our experience on one of these occasions. We came to a small hut at about 11,000 feet and asked if we might remain for the night. "Como no, Señor?" (Why not? or surely.) The hut was of brush thatched with grass, ten feet by six, a doorway but no door, no windows, a dirt floor. In one end there was a raised platform, which was the bed. The only equipment consisted of three blankets and quilts, about half a dozen tin dishes and three stones on the floor for a fireplace (no chimney). Here lived a man, his wife and four small children, the youngest a baby of six months. Being the

A Frailejone Plant about Eight Feet Tall.

guests we occupied the platform. We had all our clothes on and our blankets, ponchos, sweaters—everything available. The cold páramo wind came through the brush side of the hut with scarcely decreased violence so that we had to wrap our heads. Yet these people were living here—and ready to give us the best they had.

I was astonished at the great number and variety of the tillandsias or wild pines, most of them epiphytic on the trees, sometimes five or six species on a single tree, but some of them growing on the ground or on rocks. Epiphytic orchids were more common here than in the other parts of Ecuador I had visited though the region was rather arid.

It is well known that in tropical regions, especially at lower altitudes, the individual trees of a given species are much scattered in the forest I had an opportunity on the west slope of the Andes to observe this and estimate the degree of isolation. One species was in full flower with conspicuous red inflorescences. At one point on a hill I was able to look over many square miles of forest, and could easily detect the individuals of this species. I estimated that the trees would average one to the square mile.

The last trip with Mr. McWilliam was from Ambato to Baños and on into the Oriente to Cashurco near Mera, occupying four days. We passed the great volcano Tunguragua (16,700 feet) which was belching vast columns of smoke. The trail down the gorge of the Pastaza River takes one through scenery that is indescribably grand. From Baños to Cashurco the collecting was unusually good. In a single day I obtained 150 species of plants that I had not found before in Ecuador.

Before leaving Ecuador I ascended Chimborazo to the snow line at about 16,000 feet, starting from Urbina on the railroad at about 12,000 feet. The trip was made on foot in one day with a native guide.

MENTAL HYGIENE IN THE UNIVERSITY

By Dr. STEWART PATON

PRINCETON, N. J.

MENTAL hygiene is one of those useful but indefinable terms which is still on probation in academic circles. The term is not on the Index, but it has not been formally recognized and accepted. As the term became prominent it encountered some if not all the opposition that once was forcibly expressed against recognizing such words as health, disease, sanity or insanity as fit subjects for academic discussion.

It is not so long ago that the intellectuals did not consider health, sanity, culture and civilization as words belonging in the same category. An intellectual was expected to radiate both culture and a civilizing influence, but he did not stop nor stoop to consider questions of hygiene, either physical or mental. The times fortunately have changed. Mental hygiene redirects attention to the Greek point of view that stresses the value and relations of a sound mind to a sound body and of bodily vigor to mental alertness. As a matter of fact there is some danger now of misdirected enthusiasm and skill in advertising, giving mental hygiene the kind of prominence it neither desires nor deserves.

I hope, however, to be able to point out in what follows the kind of attention and encouragement mental hygiene deserves and expects to receive in the university. Before doing this let me say that mental hygiene represents a happy combination of the methods of art and science intended to secure a little bit more intelligent regulation of our lives. Mental hygiene, however, is not proposed as a panacea for all our ills. It does not insist that there is only one road to salvation, nor does it offer a specific remedy guaranteed to cure every form of mental and spiritual disillusionment.

Perhaps it is just as well for us to remember that one of the chief functions of mental hygiene is to point out the obvious. Those telling about the advantages of mental hygiene must expect to have the same experiences, which Professor Santayana has said generally come to those who are engaged in championing the obvious. On the one hand, some people will say it is both futile and silly to dwell on the obvious, while on the other side, there will be docile minds ready to bow before "Plain words as before some sacred mystery."

Although mental hygiene is only one half art and one half

science and does not have any promises rich in dramatic possibilities to offer, it is a very important subject. It serves to remind the academic psychologist that education should prepare a student to live in the world of reality, as well as to enjoy the protected environment of the university. A little knowledge of its principles should make it easier for members of a faculty to live together in unity, for teachers to teach, for students to learn, and for all to develop a little more intelligent interest in acquiring the art of living within their emotional and intellectual means. Mental hygiene tries to make it easier for all to catch the rhythm in the dance of life.

It is not difficult to find plenty of illustrations of the advantages the members of a faculty could secure from even a slight acquaintance with the ordinary rules of the art we are describing. I happened once to be walking with a friend who is a philosopher by profession, and we chanced to meet another professional philosopher, an acquaintance of both my friend and myself. I noticed the second philosopher responded to my greetings but took no notice of my friend. After we had passed, I said to my friend, "B. does not speak to you. What is the trouble?" "He never liked my criticism of his work," replied my friend, "so he does not notice me." "Evidently B. is an academic but not a practical philosopher," I said, "and of course it is safe to assume he is not interested in any subject as practical as mental hygiene."

Mental hygiene can be counted upon to furnish material assistance to members of committees on discipline and the curriculum in developing human and humane views on the subject of education. Emphasis is placed upon the original meaning of the word education—a drawing-out and not a putting-in process. An appreciation of this fact should bring to the attention of the teacher the importance of finding out something about the nature of the processes he expects to draw out of the pupil. What a marvelous change would take place in the whole educational system if the teacher once grasped the idea he was not engaged to superintend the storage of academic cargoes, but to direct the delicate adjustment of very complicated brain-processes.

The reaction of a good many teachers towards the statement of the fact that students have brains is similar to that of an English clergyman I met years ago in Naples, and who asked me what kind of work I was engaged upon at the Naples Aquarium. When I told him I was studying the brains of fish he sat silent for some time puffing on his pipe, but finally asked, "Did I understand you to say that fish have brains?" After assuring him that fish did actually possess brains he suddenly showed signs of considerable enthusiasm for a new discovery by ejaculating, "By Jove, that's quite an idea!"

My experience in academic communities has convinced me that if the average professor does realize that students have brains, then these authorities on education do not seem to be very enthusiastic about the significance of this information. If they did understand what it was to be the happy possessor of a brain they would appreciate what a wonderful organ the human brain is not to be thrown out of kilter more often by the varied and complex disadvantages of a thoroughly modern education. A special license is required in order to experiment upon the brains of the lower animals, but no license is required to-day from the multitude of teachers in schools and universities who are experimenting on the functions of the brains of students.

Perhaps many will consider me unnecessarily severe in criticizing institutions of learning. Let us see if this attack is justified. Recently I had a long and interesting conference with one of the chief academic representatives of one of the oldest, largest and best known of the eastern universities. "Suppose," I said to this official, "I happen to be a professor of history in the institution you represent, and Jones, an undergraduate member of my class, is not doing well in his studies. I take a personal interest in Jones, and wish to find out what the reason is for Jones's poor scholastic standing. Undoubtedly there is considerable information in the university bearing on Jones's case that may throw some light on the reason for his continued failures. In the first place, there may be items of interest contained in the results of his physical examinations, of intelligence tests, of university examinations, of reports from the schools which he attended before entering the university." We counted up, I think, seven different possible sources of information about Jones. "But," said my friend, "if you wish to get all this information you would have to go to at least seven different offices on the campus." My reply to this was that as I was presumably a very busy professor, I should not have time to get the information, and when Jones failed in his examination he would be dropped from the class and neither he nor I would know just why he was dropped. Think of educators not making an effort to study their failures intelligently! What a comment this is on our entire educational system—the one system in which we would think a careful study would be made of each failure in order to improve the methods! How the professor in the class-room loves to tell his students to profit by their failures, and yet how very little he does himself to set the student a good example in this respect. The relatively large amount of information now available in the universities would, if properly coordinated, supply the faculty with useful data about the real reasons for students' academic successes or fail-

ures. This same information if properly used would throw light upon the ease or difficulty students frequently experience either in recognizing or adjusting their personal problems.

Here is a very striking illustration of the harm often done by trying to stimulate intellectual interests in students at a time when nature is trying to protect the pupil from the meddlesome interference of teachers. The protective reaction is usually one in which lack of interest in study is a prominent symptom. Often, as has been shown by Dr. C. G. Guthrie at Lawrenceville, as the result of rapid growth associated with undernourishment, boys in the school period begin to show signs of not having sufficient reserve energy for both work and play. They seem to be and are always a little behind the game. Soon these boys develop a series of protective reactions. These responses, usually exaggerated by repeated attempts made to develop at an inopportune time intellectual interests, include signs of emotional instability, irritability, lack of interest, inability to fix and concentrate attention and a variety of other symptoms which may become permanent unless the underlying causes are removed. As a rule, the cases of these boys are not recognized and they go from school to college and out into the world sadly handicapped by mental attitudes and habits that are indicative of nature's efforts to compensate for a fundamental sense of inadequacy that can be traced directly to physical causes. If the physical causes of the mental disturbances had been removed, then the pupils would have adjusted their lives and developed healthy intellectual interests.

A slight knowledge of mental hygiene would often make it easier for the teaching staff to understand that pronounced cases of mental disorder, now occurring all too frequently among the students, exhibit mental peculiarities that are not in any way specifically different from those met with in the average person. The little personal prejudices, obsessions, fixed ideas and various complexes from which we all suffer differ merely in degree but not in kind from those occurring in psychotic conditions. If then, it is to be a function of the teacher to assist students to develop mental poise, to keep their minds as free as possible from prejudices and obsessions, and to give assistance in cultivating the special emotional attitudes towards life favorable for the growth of genuine culture, attention should be given to the pronounced disorders in order that the educator may be familiar with the forces shaping the organization of every personality.

I shall not say very much about the incidence of mental disorders among the undergraduates in our universities. That is a

topic deserving special treatment. Before I leave this subject, however, I wish to say that the occurrence of pronounced mental trouble during the university period and the indications in other cases of serious trouble brewing, if difficulties in adjusting life are increased above a certain point, is very much greater than I had any idea of before undertaking these studies.[1] There is no reason to be alarmed in regard to the present rate of incidence of mental disturbances among the undergraduates, as we have no figures to indicate whether the curve is rising or falling. The presence, however, of such a relatively large number of cases in itself is a very serious problem. It is just one more indication of the fact that man is paying an absurdly high price for what we call modern civilization.

One result of ten years' study of the emotional and mental life of university students has made it very clear that what is needed is adequate provision to make a careful correlation of the physical and mental characteristics of one or two classes of students observed during the four years of undergraduate life. I feel confident that if adequate provision were made for completing a research of this character it would be one of the most valuable contributions that could be made to education.

During the period devoted to this research the members of the staff engaged in the work would be receiving a very valuable training that would enable them later to carry on the work in other universities, colleges and schools. Already there is great need for investigators trained in the methods of psychobiology to organize and direct the work in various institutions. At present I have been unable to recommend candidates with the training and experience essential for studying the problems of human behavior and conduct to three university presidents, and at least a score of prominent directors of schools who have expressed their intention of starting work along the lines I have indicated in the institutions they represent.

The establishment of departments in our universities for dealing with the problems of human behavior and conduct would accomplish the following objects:

(1) Indicate that at last the chief study of mankind has been recognized as the study of man.

(2) Make provision for discovering the signs of mental disorders occurring in students at a time and under conditions when treat-

[1] I wish to take this opportunity of expressing to Dr. Joseph Raycroft, director of the department of physical education and hygiene, and his associates, as well as to Dean Howard McClenahan, of Princeton University, my appreciation of the assistance they have given me in making these studies.

ment would often prevent tragic occurrences and give the patient a much better chance of making a satisfactory readjustment in living.

(3) Assist students to correct many of the personal peculiarities and unfortunate habits that so often stand in the way of their securing more solid satisfactions, genuine pleasures and greater efficiency in living.

(4) Bring home to educators the vital importance for our civilization of getting completely away from the present academic attitude of stressing the importance of measuring merely the quantity of facts students have accumulated, and of paying so little attention to how a student thinks and above all how he meets the exigencies of actual life.

To any one at all familiar with the rather narrow views on education now frequently expressed by the intellectuals, it is apparent how important it is to turn our attention to the biological significance of education.

If the information relating to the individual student's educational problems, which is now on file but relatively seldom used, were applied, some important results might be expected. In the first place, the student would receive from academic authorities more intelligent assistance than he does at present in the adjustment of his personal problems. In the second place, the study of individual cases would assist the instructor to acquire a new and very much broader interest in the development of teaching as a fine art. A practical result of paying as much attention to elevating the standards of teaching as is now done to raising the standards of examination would make it possible for students intending to enter professional schools to do this much earlier in their careers. I believe that if sufficient attention were given to improving the art of teaching and in aiding the student not to accumulate information but to improve the character of his mental processes, at least two years could be saved those entering professional schools.

For the past two decades there has been a constant effort made to raise the intellectual standards in the university that is out of all proportion to the attention paid to raising the standards of teaching. Probably the medical schools have been the worst offenders in this respect. The officials have made the naïve assumption that the introduction of laboratory and clinical methods has been an indication of improvements in the art of teaching. Of course, to a very limited extent this is true, but in the medical schools as well as in other departments of our universities educators are still obsessed with the notion that man can afford to fix his attention

on the goal in view without giving equal consideration to the means whereby the end is reached. The high rate of incidence of insanity, the great increase of functional nervous disorders, the marked tendency of large numbers of people to dodge reality by taking refuge in absurd forms of mysticism, the astonishing exhibitions of fear of self, exhibited in hysterical eagerness to over-emphasize social relations and to use communistic cravings as blinds to conceal a defective sense of individuality and seriously disorganized personalities are all tragic evidences of what we must expect to pay for thinking so little about the means we use to get an education and to become civilized. The formal recognition of mental hygiene by our universities will at least indicate the willingness of educators to listen to the question whether it is not worth while before it is too late to take more intelligent steps to conserve the brain-power of our race. The fact that society is coming more and more to rely on prohibitive restrictions to direct the stream of human energy should be recognized as a danger signal of startling significance.

STABILITY

By Professor T. WINGATE TODD
WESTERN RESERVE UNIVERSITY

INHERENT conservatism and extreme reluctance to change or even to contemplate change in any time-honored belief or institution —this is the charge upon which modern mankind is thrust into the dock. The indictment is made with vigor and forceful originality in James Harvey Robinson's "Mind in the Making." And much of the heart-searching among thoughtful people of to-day, progressive and conservative alike, revolves around this very problem. The question of the author is the question which every one is asking himself in these times of unprecedented complexity, "How are we to rid ourselves of our fond prejudices and open our minds?"

I do not presume to answer this question or even to assume knowledge of the direction in which the answer probably lies. That is for the future. But one phase insists in thrusting itself forcibly upon my attention, namely, how is it that an attribute, once most significant for man's progress, may in time become a positive menace to his welfare and his true development?

There is no doubt that this is precisely what has happened, although in the realm of the mind, with our present knowledge, it would be a thesis difficult to prove. Perhaps in this very conservatism lies the essential difference between man and other living things. It is not without reason that man has put himself upon a pedestal, has come to consider himself a creation apart, as something very special among the various forms of life upon the earth. But when he tries to explain wherein this difference really lies he is inarticulate. One can identify the faces of one's friends but finds it difficult to describe them; likewise one feels sure that there is something different about man but can not define in set terms what this difference is.

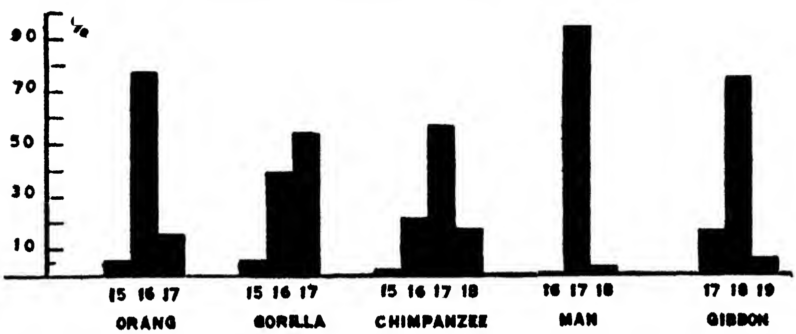
Of course one may say that psychologically man is "different." Our standards of psychological measurement are, however, still obscure and observation along this line difficult and many times uncertain. But nothing is more sure than that body and mind are indivisibly bound together and for this reason I am attempting to define the difference physically.

During recent years it has fallen to my lot to study rather intensively the variability in pattern of man's bodily features and, in order to have some standard of comparison by which this variability may be judged, I have found it instructive to use as a contrast the variability in pattern of the bodily features of other forms of

life which are at least similar in design. It must be understood that in using the body of the anthropoid ape by way of contrast we are, for the moment, assuming nothing regarding origin. We are bound to admit that both man and the anthropoid share life in common, that both are warm-blooded and that they bring forth their young in the same manner. Beyond these facts our argument carries us no further in the present discussion. We can not speak solely in terms of absolute values: we must have some standard of comparison: and there is no better or surer standard of comparison by which we may point the contrast.

The example which I propose to take as a test is drawn from the very core of man's physical being, namely, the character of the vertebral column, a feature which every one would admit is ancient and fundamental. In the chest and loins of a man's body there are, as a rule, seventeen separate bones or vertebrae But if we

VARIABILITY IN NUMBER OF THORACICO-LUMBAR VERTEBRAE.



enumerate the bones in a large number of human beings, we find some people who have, not seventeen, but sixteen or perhaps eighteen vertebrae in this region. This variability in itself is rather striking, for we have reason to believe that the earliest mammals to make their appearance on the earth had nineteen, whereas certain mammals of to-day have more than nineteen, but others have less. We are not to emphasize, at the moment, the significance of this passing observation. Our immediate problem concerns itself solely with the amount of variation in man.

To render clearer the variability in number of thoracico-lumbar vertebrae found in man, I append a chart showing in black columns the percentage of individuals possessing, respectively, sixteen, seventeen and eighteen. The series upon which these observations were made totals about 850 skeletons; there is no doubt therefore of its essential accuracy. The percentage of individuals possessing eighteen vertebrae in chest and loins is very small and the percentage with sixteen is negligible. Now for comparison I have included black columns analyzing the similar bones in existing anthro-

poid apes. The difference between all these anthropoid figures and that representing man is sufficiently distinct. The characteristic of man is his stability of pattern contrasted with the instability of pattern in the anthropoids. In other words, this means that man differs from these creatures, not so much in his physical features, striking though even this difference may be, but he differs from other creatures in being able to retain a definite bodily pattern. He has not simply attained an ascendancy among living things, but he has been able to maintain that ascendancy and transmit the ascendancy to his offspring with an assurance far beyond anything seen in other creatures. Here, then, is the secret of man's original success. His constancy of pattern, his hereditary retention of bodily perfection, as the French style it, has given him his paramount position in the world of life.

When we assure ourselves that mankind is a creation apart, has characteristics which clearly differentiate him from everything else that breathes, we unconsciously refer to this hereditary stability, call it dependableness, if you will, which undoubtedly is characteristic of man's mind, as it certainly is a dominant feature of his body. It is the fly-wheel by which, in the past ages, his progress has been rendered orderly and continuous.

Let us refer once more to Robinson's stimulating essay:

> There is some reason to think that the men who first transcended the animal mind were of inferior mental capacity to our own, but even if man, emerging from his animal estate, had had on the average quite as good a brain as those with which we are now familiar, I suspect that the extraordinarily slow and hazardous process of accumulating modern civilization would not have been greatly shortened. Mankind is lethargic, easily pledged to routine, timid, suspicious of innovation. That is his nature. He is only artificially, partially and very recently "progressive."

Exactly. The very characteristic which has made man what he is now menaces his further progress. Lethargy and routine are mordanted in his very bones. And yet in spite of this we are witnesses to-day of an extraordinary versatility and energy of mind as though the mind had suddenly shaken off the lethargy which characterizes the body; of a groping into regions of thought and possibility unexplored. What wonder that society is sick. But there is ground for optimism. The ever-spinning fly-wheel may and probably will result in many a troubled and anxious year. The conservative mind will be pained beyond measure and the progressive barely maintain his patience. But in the end, upon this solid basis of control which is man's special inheritance, there will be built a better understanding, a larger and more tolerant comprehension of those fundamental truths by which alone our bounding civilization shall adjust itself to the immutable facts of life.

WHY I TEACH EVOLUTION

By Professor WILLIAM PATTEN

DIRECTOR OF THE FRESHMAN COURSE IN EVOLUTION, DARTMOUTH COLLEGE

It is often said that the moral and religious effects due to the teaching of evolution are disastrous; and even if this is not the case, that evolution, in itself, is not a suitable diet for college freshmen. As our experience does not confirm either of these assertions, it may be worth while to state why and how we teach evolution at Dartmouth.

For the sake of simplicity, and to assume undivided responsibility for this statement, I shall usually speak in the first person.

In the first place, I teach evolution because, in the practically unanimous opinion of those who in one way or another have devoted their lives to the study of nature-action, evolution, or world-growth, is the only logical and unifying concept of natural phenomena there is.

It is a concept that not only helps us to understand what is going on within us and about us, but one that is constantly leading to new revelations in every field of human thought and practice. It is the one basic idea implied, or specifically expressed, in every phase of college and university teaching.

It is essential, therefore, that every young man at the outset of his college career should understand what that idea is, what are the chief facts on which it is based, and what are some of its social, ethical and religious implications.

In the second place, I teach evolution because I am confident, and it is a confidence fully justified by long experience, that the teaching of evolution is the only way to bring back a living God into those fields of human thought and experience from which the teachings of "high-brow" philosophy and "low-brow" religion are excluding Him with extraordinary thoroughness and rapidity.

For there are only three basic concepts of the universe that are possible; either the world stands still in its tracks, as it was made and now is; or else it is going, sooner or later, to destruction; or else it is growing or moving onward in a unified, evolutionary way to what we call higher and better things.

I can not see how there could be any evidence of God in a world that is stationary; and certainly not in a world that is on its way to destruction. If I believed in either of these alternatives, I can not

see how I could have any faith in the existence of a living God, or any worthwhile purpose in life.

On the other hand, the manifold evidence from all branches of science and from everyday human experience that the world is a living, growing world, everywhere and always unified by "natural laws," is to me the surest and the only available evidence that there is a God-like *method* and a God-like *purpose* in it all.

Thus the study of the ever-marvelous phenomena of evolution, done with a full appreciation of their deeper significance, should be the very best way of strengthening religious feelings and unifying social purposes. And that is precisely what it does do, according to the practically unanimous testimony of a surprising number of students who had already begun to call themselves hopeless and aimless "atheists," as well as those who were firm believers in the conventional doctrines of Christianity.

It is evident that without some hopeful, common-sense philosophy of life to vitalize and coordinate our educational system, root and branch, with a convincing and consistent terminology, that system will be fruitless and ultimately self-destructive. For without it, the more we learned the less we would know. Its highest teachings would culminate, as indeed they too often have culminated, in nothing but moral uncertainty and agnostic suicide. It would be a despairing confession that civilization has reached the end of its rope and is doomed to a crashing disaster commensurate with the magnitude of its super-structure and the inherent weakness of its foundations.

The mind refuses to contemplate the horrors of that disaster or the hopeless task of again climbing out of a bottomless pit of ignorance, only to rediscover that life can not logically justify its own existence, and that, after all, it is not worth the effort.

The third and perhaps the principal reason I teach evolution is because the *methods of evolution exemplify the successful usage of the highest ethical and moral principles.* They show us the ideal methods of democracy and of Christianity in successful operation on a universal scale.

Evolution, indeed the very essence of evolution, as we understand it, is a democratic, creative process that has been going on for an infinitely long time; it is still going on all about us, and in it we must play our own parts in cooperation with all its other working members. It is our supreme privilege, as intelligent beings, to understand something of its working principles; but we must understand them to some extent rightly before we may hope to use them successfully in our own creative efforts, of whatever nature they may be.

It may seem presumptuous to say that many scientists, as well as the vast majority of intelligent laymen, do not rightly understand what evolution is or what the working methods of evolution are. The facts, however, clearly point to that conclusion. Scientists themselves are largely responsible for this unfortunate situation. They have been too much absorbed in their own little fields of work; and few of them look beyond those fields, or take the trouble to tell in untechnical language what they have discovered, or what, if anything, they think about evolution *as a whole*. They have left all this summarizing and simplifying for the layman to work out for himself, as best he may. But they are now beginning to recognize their obligations to youth and to "the man in the street," as well as to themselves, and are trying to fulfil them.

A brief panoramic view of the whole subject of evolution, such as we give our freshmen, simplifies, after their first amazement, many of their most perplexing problems, and clarifies our own ideas in a surprising way. For when we inspect with the instruments of science the infinitely large affairs of the heavenly bodies, as well as the infinitely small affairs of atoms and molecules, plants and animals, we readily get the impression that there is a lawful continuity of action in the administrative methods of nature and an insistent trend or drift in the creative results which is clearly indicative of some sort of creative purpose. And eventually, in spite of our prejudices, we are *compelled* to believe that that purpose is the bringing of organic life, of consciousness and intelligence into being on this planet and on many others.

And finally we begin to realize that that purpose is actually accomplished by the cooperation of a multitude of different yet inseparable, "actors"; by many workers or servants, great and small, "living" and "dead," each one, according to its kind, helping and controlling the others in a universal service for that one creative purpose.

And so we see enacted before those "eyes" which science gives us the universal democracy of the idealist in its living and growing reality. It is not surprising that freshmen are so intensely interested in this great creative drama or that they so readily perceive its moral and ethical significance.

We begin the course with a warming up discussion of the more familiar aspects of growth, such as that of a college or some other similar institution. In this pioneering overture, the purpose of the course is explained, its contents outlined and the keynote to the moral treatment of the subject is emphasized.

It is hopefully assumed that with a little insistent pressure the

point of this subsoil plow will eventually penetrate the cold of the freshman's mind deep enough to break up its hardened crusts of prejudice and prepare a naturally fertile soil for further cultivation.

The next part, called the "Evolution of the Physical World and the Preparations for Life," briefly describes how the scientist makes his discoveries, the instruments he uses for that purpose and what those discoveries mean to him. It tells why the impression is gradually born within him that the physical world is a growing world. It shows that the same elemental agencies, or protons and electrons, atoms and molecules, which play such an important part in the upbuilding of suns and stars are the same agencies which are ultimately used in the upbuilding of living plants and animals; the same ones that provide suitable homes and foods for their continued existence; and the same ones whose chemical activities, whose rhythmic and radiant emanations, such as light, heat, gravity and electricity, direct and control in an orderly way their inner life and their behavior.

From this preliminary study of the physical universe we readily get the impressions that there is an underlying similarity in the make-up and mode of action of the entire universe; and, in spite of what at times may appear to be utter confusion, with apparently no other government than "chance" or accident, that there is after all a resultant order and lawful administration throughout all its affairs.

We find that there is no measurable gain or loss of creative power in this administrative business. *The only recognizable gain is in rightness,* or in those more constructive ways of doing things that we call growth or evolution. We find that the old bugbears of materialism and mechanism finally vanish in those plus and minus symbols of creative energy called protons and electrons, which in the last physical analysis make up the so-called "material" universe. And finally we come to realize that as the silent night, through the instrumentality of the radio, now speaks to us in a multitude of intelligible voices, so through the instrumentalities of science, the "dead" physical universe now speaks to us in intelligible and inspiring terms.

This is not the old, unconvincing mystery of the watch and its maker; it is the clear revelation of a universal creative method. If we may not say that this primeval upbuilding of chemical and celestial bodies was "intended" to serve as the ways and means of a life to come, we may at least say that the whole process of physical evolution has no other intelligible meaning. For it is manifest that

without these particular agencies, or even with any measurable modifications of their peculiar qualities and proportions, protoplasmic life would be impossible on this planet or on any other. And so here, if anywhere, the making and the adequate furnishing of many mansions for eternal life is convincingly revealed.

Under such conditions, life in due season made its appearance on this earth, plants fitting themselves to the life-giving resources of the sunlight, the air, the waters and the soil; animals fitting themselves for a more roving life within the prescribed limitations of their terrestrial habitats.

And then these two great kingdoms of life, each one so different from the other, intermingled in one great democratic social life; each kingdom, like man and wife, being dependent on the other for the fulfilment of its own creative possibilities; and each and every member performing for the others, in its life, or in its death, an amazing variety of essential services.

From this more remote, unprejudiced point of view, the little tragedies of human life gain new significance; for the bodily sacrifices or the expenditures of materials and energy essential to any bodily service are seen to be an essential phase of life itself. Thus the significant fact is foreshadowed that effort, pain and suffering and the successful overcoming of difficulties is essential to that triumphant aspect of beauty we so much admire, and to that feeling of well-being and of well-earned success we call happiness; that even death itself is a spur to life; and that, in spite of death, life really exists and thrives in all its beauty and with all its glorious possibilities.

The second part deals with the more important stages in the further evolution of plant and animal life; and the third with the evolution of human life and culture.

Organic evolution is the subject generally in mind in discussing evolution, and it is the one least understood and most grossly misrepresented by the popularizers of science.

Such writers seem to take a special delight in unbridled exaggeration. They may depict life as something wholly "vitalistic" or wholly materialistic or mechanistic; or as a "bloodthirsty" struggle for existence that is governed by nothing but brute force and pure selfishness; or as a heavenly peace where no one or anything works except man; or they may picture animals, including man, as mere jumping-jacks made of immutable germinal corpuscles pulled by immutable hereditary laws. They like to call themselves special advocates, or opponents, of Darwinism, or Lamarckism, or Weismannism, or Mendelism.

But life is not as simple as these rigid formulas imply. We try to show that all these "isms" and many others play their appropriate parts in various ways and in various degrees.

For plant life and animal life, whether conscious or unconscious, is much like our own. It is a tangled web of success and failure, tragedy and comedy; with the freedom of trial and error and the bondage of enslaving circumstance; with exhausting, killing work and restful, regenerative leisure. It may have the cold placidity of ocean depths or the rushing, sunlit excitement of mountain torrents. It is governed by internal biochemical and "mental" agencies, and by external agencies, cosmic, climatic, geographic and social. It displays the perfection of mechanistic and economic devices and the wildest extravagance; utter selfishness and supreme altruism. All things that live are animated with their own little purposes and all are buffeted about apparently to no purpose. But ultimately the supreme purpose of life and of evolution is accomplished.

A living body is a little, active system existing within and sustained by an infinitely large environmental system. And so the chief problem of animal life is to select, so to speak, a definite plan for the upbuilding and progressive improvement of its own body, a plan that will always be in workable or cooperative harmony with that of its environments. That body, therefore, *should always be sensitive to its environments and adaptively adjustable to them.* In other words, it should have the greatest possible locomotive powers or freedom of action, and it should be self-feeding, self-steering and self-perpetuating.

But to attain that end, the body must be *architecturally oriented* in all its structural details, as well as in its main plan, to the great, directive and controlling agencies of its outer world, such as light, air, gravity and food supplies, so that it can rightly respond to their informing influences. Otherwise it would not be able to discover, to capture and to assimilate its necessary food supplies or to avoid disaster. And finally it must always keep its combustion fires burning and *make some profit* out of the business of living. Otherwise the evolutionary progress of life would be impossible.

There are many different ways of upbuilding multicellular organisms, each one producing a characteristic "type" of bodily architecture, such as spherical, branching, disc-like, radial, spiral and ones that are variously distorted or crooked.

But such "structural" plans, even after many millions of years

of experimental trial, have produced but little in the way of progress and evidently can maintain life only on its lower levels.

There is only one plan that has met all the requirements of continuous life and progress. That is the triaxial-gradient plan or symmetrical growth in three right-angled planes. It produces bodies of six different sides (right and left, head and tail, neural and haemal), in which no two points will ever be exactly alike, however small the body may be in the beginning, or however large and complex it may ultimately become.

This basic plan, which is capable of the greatest variety of adjustments adapted to special conditions, has persisted through many geologic eras. The more important internal adjustments that have been made to meet the new requirements of bodily growth gave rise to that long series of animal classes, such as certain worms, arthropods, fishes, amphibia, reptiles and mammals, which were the more immediate products of those adjustments, and which show us, class by class, the great upward steps in the development of that plan and in the development of man's bodily structure and mental powers.

When we survey this long genetic series, the most impressive fact to the student of comparative anatomy and physiology is the essential identity of the great systems of bodily organs and their component parts throughout the entire series.

The main improvements that have been made from time to time, such as for example a one, two, three or four chambered heart, are what chiefly distinguish one class of animals from another. They may appear in themselves as trivial anatomical details, but they are just the kind of adjustments any good engineer would have made to meet the new demands of the time, without seriously interrupting the continuity of vital service. Hence if the basic plan was essentially right in the beginning, and the working materials fit for the purpose, these readjustments may be made indefinitely, with the assurance of getting better results *in accordance with the rightness of each readjustment.*

And that apparently is the way organic evolution is accomplished. For there is always a "new demand" to meet the new conditions produced by preceding achievements. And it is just because those demands are fulfilled or because certain adjustments are made which do have great functional and creative value that a new and higher class of animals quickly comes into being, with still other demands and with still other creative possibilities.

But organic evolution is not all mechanistic, in this narrower sense. It does not solely consist in the upbuilding of organized ani-

mal bodies. Each animal is itself a working unit in a worldwide social organization. In this more fluid social life fixed architectural patterns are less in evidence, although the economic principles of mutually sustaining services are there as immutable and as much in evidence as in the anatomical architecture of the individual organism.

Moreover, hand in hand with the upbuilding of organized animal bodies and of organized social bodies, those qualities gradually emerge from the alchemy of life which, for lack of a better name, we may call spiritual qualities. They successively emerge, but from no particular part and without any definite cleavage planes, as various degrees of purposeful reactions, bodily and social, such as instincts, intelligence and consciousness. We can not anatomize these qualities in materialistic terms. Yet we can not divorce them from material things, for they are apparently the riper products of architectural organization and in turn are knowable only so far as they have a measurable or fruitful influence on the structure of such things.

These more complex animal instincts and social reactions are marvelously effective in the grand strategy of evolution, even though in the special emergencies of individual life they may be as tragically ineffective as the fluttering of a bewildered moth in the alluring light of a candle or the puttering of a negatively heliotropic senator in the light of international peace. Nevertheless, these less adjustable instincts have insured the perpetuation of life and progress, and they have prepared the way for the birth of intelligence that may be used to advantage in just such emergencies. But human intelligence, if it happily exists in an appreciable degree, is only a supplementary addition to instincts, not a substitute for them.

In fact, intelligence, in spite of its frequent abnormalities and "metaphysical" absurdities, is merely a more adjustable reaction to environments than hearing or seeing or instincts. It is a new, synthetic awareness that adds a new logical control to the steering gear of animal behavior. It is the crowning but still acid fruit of life, which serves to put life into wider communication with its environmental Creator.

Imagine, if you can, human beings that are merely intelligent, and just because of their intelligence, let us say as shopgirls, priests or professors, voluntarily surrendering their possessions to their betters, or joyously sacrificing their lives for the sake of prospective babies and posterity. You may easily imagine many familiar voices exclaiming "Well, I should say not! No surrender to babies and posterity in mine, just yet, if you please."

And yet that is precisely what life has done for untold millions of years without intelligence and still does in spite of intelligence. But it is done only under the *secret compulsion* of all those "mechanistic" reactions, appetites and passions, of all those animal instincts and selfish ambitions, the fulfilment of whose imperative "demands" makes the self-sacrifice of altruistic services the chief aim and the chief pleasure in life.

These grosser animal mechanisms, therefore, have their strategic purpose, and it was essential to perfect them and to establish their supremacy before the more "fickle will" of man could be safely allowed to assist in the operation of his own body or before his more spiritual ideals could attain their maturity. A jellyfish probably has no spiritual ideals, but if it had all the wisdom of the prophets and the ideals of a Sir Galahad, it would still have to pursue its ideals in uninspiring waters and fight its battles with gelatinous tentacles.

One of the very great achievements of modern biology was the revelation of the basic mechanism of heredity. This was largely due to the earlier discoveries of the microscopic architecture of the germinal elements, their lawful behavior in the initiation of a new life and their extraordinary stability in a great variety of conditions. At a later period it was discovered that these germinal phenomena could be mathematically correlated with the laws of inheritance, and that certain inherited characters of the adult organism might be logically interpreted as resultant products of certain corpuscular units having a definite quality and number and a definite location in the germ cells.

And now the biologists, with astonishing assurance and success, are beginning to map out on the minute germinal threads called chromosomes the distribution of these *"germinal units"* (which are somewhere near the order of magnitude of the larger molecules) and to correlate them with hereditary *"unit characters"* of the adult organism.

That is, the biologists are now doing much the same sort of thing the physicists and chemists do when they "correlate" atomic structures and action with their resultant products, such as light and other radiant activities.

But these stabilized "germinal corpuscles" and rigid Mendelian laws of the modern science of genetics do not make life a purely germinal mechanism nor do they preclude the existence of still other stabilizing and controlling agencies of a more general character. In fact, they make their existence more clearly imperative.

For no germ could exist, however righteous or perfect it might be in itself, without the right kinds of environmental soils to grow up in and to grow up with.

And so organic genetics, in its narrower meaning, is only a very small phase of a universal system of evolutionary genetics, in which many different classes and orders of *rightly stabilized heritages,* cosmic, terrestrial, organic, germinal, parental and social, play their directive and controlling parts.

Indeed, one of the most instructive lessons of organic evolution is the gradual development of an elaborate system of parental provision, in which *all* bodily agencies, such as muscles, nerves, blood, bones, instincts and intelligence, cooperate to provide better ways and means for the growth of the purely germinal elements.

From era to era and from class to class, up to man, we may see with most impressive clearness the progressive enlargement of the nervous system and many adaptive modifications of mental and bodily powers, as if they were made for the sole purpose of giving greater abilities and greater freedom of action to parents, in order that they might use those powers for the better administration of their germinal affairs. We see the body making larger and larger food provisions for the germ, and enclosing both the germ and its food supplies of eggyolk and albumen in more ingeniously constructed containers. We see the parents using better ways to broadcast their eggs or hiding them in more secret places or making better nests or homes in which to incubate or nurse them. And when the young are liberated from their more rigid, disciplinary confinement, we see the parents foraging for them, protecting, guiding and educating them to the utmost of their ability, mental and bodily.

Thus the parental body, with all its varied powers and resources, is as much a working heritage for the germ as the germ is for the body.

But even that is not the whole story. For hand in hand with the evolution of these bodily and germinal powers goes the evolution of the broader and looser web of social life. And there, without regard to the ties of kinship, high and low, old and young, plants and animals play their respective parts in cooperation with one another and with their physical environments, to form one great ecologic system of mutually profitable exchange.

All these enlargements of life, therefore, are the products of some kind of cooperative exchange which, on the whole, has been mutually profitable. The peculiar give and take of cellular life or the biochemical upbuilding, unbuilding and exchange involved in

every protoplasmic act is called metabolism. It is the very essence of continuous vital action. On a larger scale, the metabolism of creating, destroying and preserving social individualities and the profitable exchange of social products is the essence of social life; and on a still larger scale, *a similar metabolism is the essence of all the changing phenomena of nature-action, including the making and destroying of such things as solar systems.*

Thus the real meaning of the pyramidal upbuilding of an interlocking directorate of mechanistic heritages, cosmic, organic, germinal and instinctive, becomes apparent, for otherwise there could be no stable or righteous foundation for the crowning products of intellectual and spiritual life.

And if we substitute "established law and order" for "mechanism," for that is what that disreputable word really means, the moral and ethical significance of the entire system of evolutionary genetics is obvious. It is also obvious that the outstanding teachings of evolution are the same as the familiar teachings of religion. For the universal reign of law and order, which it has been the special privilege of science to reveal, is nothing more or less than the revelation that nature is a unified cooperative system and that those better results, called evolution, are only achieved through better mutual service by all its constituent parts and by their better submission or adaptation to one another's requirements. That is the essence of the moral and ethical teachings of Christianity as it is the essence of the moral and ethical teachings of evolution.

And the law of "natural selection," which is the essence of the much maligned "Darwinism," is in reality the expression of a discriminating, selective action in nature, in effect identical with the discriminating disciplinary laws of religion.

This disciplinary natural law merely means that whatever is fitting or right or true, whether it is physical or organic or vital or spiritual in its nature, shall prevail and shall yield its appropriate fruits. If it is not fitting or if it is not right or not true, it shall be fruitless and shall not prevail.

In other words, truth has a saving power and a creative compulsion of its own. We call it the compulsion of intelligence. That is *why* man is compelled to seek the truth and to use it for his own salvation and betterment. And the *doing of that* is what we call science. But if we do not use the truth when it is discovered, if the truth when it is discovered does not make us work and direct our work, if it is not reverified in terms of human conduct, science will be sterile; it will neither bear its appropriate fruit nor have the vitality of reality.

Thus this compelling pragmatic law, which Darwin so clearly saw in operation in plant and animal life and which he called "natural selection," is the same law that is so clearly expressed in biblical teachings, as for example:

> *And even now the axe is laid unto the roots of the trees: therefore every tree which bringeth not forth good fruit is hewn down and cast into the fire. . . . But the root of the righteous shall not be moved.*

Lowbrow fundamentalists and highbrow agnostics will please take note of the "even now," and the reality of the "axe."

And so, if we attempt to summarize the creative methods of evolution and to estimate their directive influence on ourselves, physically and mentally, it is not surprising that the descriptive terminology of science inevitably changes into the moral and ethical terminology of idealism or religion.

This means that in the last analysis religion is merely a different name for science; the one being chiefly concerned with the immeasurable Oneness or Godliness of nature-action, the other with its measurable Manyness, or its distinguishable parts. But both, in their own distinctive ways, seek to discover, to interpret, and to utilize the same realities; and when that is rightly done they will be in functional agreement; that is, they will dictate to mankind essentially the same conduct and justify essentially the same faith.

And science has already visualized the same realities as religion. For in the larger aspects of nature-action, the scientist everywhere sees in operation that natural trinity of creators, destroyers and preservers, with the selective law presiding over all, which all great religions have graphically symbolized, in one way or another, as living gods and demons, and which have always served to direct human thought and human behavior. And the whole tendency of science, as that of religion, has been to reduce these several agencies to one operating cause, or one God.

Scientists everywhere see a certain individualistic *variability* or freedom of action in dead things and in living things, which eventually leads to creative innovation and invention. But that freedom of action is always subject to some external limitation and compulsion or to a restraining and guiding *discipline* which limits certain adventures by destruction and *compels* a more lawful and more righteous behavior.

There is always in evidence the *creation* of a new order of things by the cooperation of those more durable instrumentalities called *heritages*. And since they are eventually utilized as aids to some-

thing else, that process has the essential attributes of *sacrifice, benevolence* and *altruism.*

There is always in evidence some selective *destroying, correcting* or *renovating* of what is no longer fitting or adapted to the new order of nature; and always some selective stabilizing or *preserving of the more righteous ways of doing things, which, because they are more righteous, are more fruitful or creative.*

In accordance with our respective temperaments and the scope of our vision, some of us can see and can wisely profit by our seeing some one of nature's metabolic trinity at work much more clearly than either of the other two. Few of us can duly appreciate all three of them, especially when the destroyer operates on our most cherished possessions.

Thus science and religion offer the same incentives to action and have the same purposes to accomplish; and science expresses in her more comprehensive formulas precisely what all the great religions of the past and present have tried to express in their teachings, but without that sure and intimate knowledge of nature-action which science gives us and which is so essential to the truthfulness and sanity of any kind of religion.

I repeat, there is no difference between what is vital in science and what is vital in religion. In fact, underneath, science *is* religion and religion *is* science. The differences which cause so much confusion are in their protective coverings of dogmas, ceremonials and procedures. They are differences between people; between those with more or less scientific qualities of mind and those who have little or no such qualities.

And so, it seems to me that the study of evolution *as a whole* more than anything else will help to minimize the antagonism between religiously minded and scientifically minded people and will help them to work more peacefully and happily together. For young and old, for highbrow and lowbrow, the study of evolution makes life more significant and more beautiful. It justifies their faith and fortifies their ideals. It makes God a more imminent reality. It helps all of us to understand the purpose of life, and how to accomplish it.

That is why I teach evolution.

THE PHYSICAL BASIS OF DISEASE

V. FLUID ACCUMULATIONS

By THE RESEARCH WORKER

STANFORD UNIVERSITY

"As our fifth group of diseases," continued the research worker as the train pulled out of Ogden, "I have selected diseases due to the accumulation of fluid or exudate in important organs or parts of the human body. Such fluid accumulations may give rise to a wide variety of symptoms."

"That reminds me," said the lawyer. "I have a fluid here that produces very agreeable symptoms. Will you join me?"

"As we are about to enter the Utah desert," said the manufacturer, "it will be wise to do so."

"The fluid that accumulates in the body in certain types of disease," continued the research worker, "may vary from a clear, water-like material to thick creamy pus. In certain cases the fluid may be coagulated to a butter-like consistency. The fluid often contains blood. In extreme cases it may consist almost exclusively of blood. The amount of fluid may vary from a few drops to several quarts.

"Probably the simplest example of fluid accumulation in external parts of the body is the watery accumulation in the deeper layers of the skin in dropsy. Several pints of fluid can often be drained off from a dropsical skin by the insertion of a hypodermic needle. This fluid is usually nearly water-white in color, with no admixture of blood.

"Aside from physical discomfort, the main significance of such a fluid accumulation lies in its indication of abnormal conditions in certain vital organs. Dropsy of the skin can be produced in animals in a number of ways. The administration of certain toxic substances, for example, will so injure the blood vessels that they no longer retain the fluid portions of the blood. There is a resulting constant outward leakage of fluid through the capillary walls with the production of dropsy of the skin and other parts.

"Other familiar examples of fluid accumulation in external parts of the body are the accumulation of pus in ordinary boils and pus accumulations in the joints in certain types of acute rheumatism, particularly in gonorrheal rheumatism. Such pus accumu-

lations are readily reproduced in animals by injecting certain disease-producing microorganisms. The pus so formed is often more or less mixed with blood.

"Pus is one of the most interesting biological products. It is strongly antiseptic, able to kill large numbers of disease-producing microorganisms. Its antiseptic power is about equal to that of one per cent. carbolic acid. Pus also contains digestive ferments, with which it is able to dissolve dead tissues.

"A somewhat different type of fluid accumulation in external parts of the body is brought about by mechanical occlusion of the sweat ducts. Such occlusion occasionally produces numerous small bladder-like cysts in the skin, each filled with clear, water-like perspiration. Occlusion of the minute oil ducts occasionally causes deep-seated cysts in the skin containing white, putty-like, greasy masses. If untreated, such oily cysts or wens may reach enormous size. You have all probably known individuals with disfiguring wens on the scalp or neck."

"The janitor in our office building has a wen the size of a fist," said the lawyer. "Refuses to have it removed on religious grounds. A queer customer. Wouldn't allow his wife to be given chloroform during delivery. Said it was contrary to the Scriptures. 'Children must be born in pain.' "

"Religious objection to the use of chloroform in obstetrical work was common fifty years ago. Prominent clergymen preached against it. I believe there is no official objection on the part of the church at the present time."

"Numerous examples of fluid accumulation are found in internal organs. One of the simplest examples is abscess formation in the heart walls. If a small amount of pus from a boil is injected into a vein of a rabbit, so that the pus is mixed with the circulating blood, abscesses or boils will often form in the heart walls. If the rabbit is killed three or four days later, portions of the heart muscle will be found distended with pus. Why the infectious agent localizes in the heart muscle, often without involving other parts of the body, is not known.

"Abscesses of the heart muscle are occasionally found in human beings. Heart abscesses may heal spontaneously, the pus being absorbed or carried away by the circulating blood. In severe cases, heart abscesses so weaken the heart walls that rupture takes place, causing instant death.

"A more common fluid accumulation in the circulatory system is fluid accumulation outside of the heart itself, in the sac or bag

in which the heart is suspended. This fluid may vary from a clear, water-like material to thick, creamy pus, often clotted to a butter-like consistency. The effects of such fluid accumulation in the heart sac are largely mechanical and depend upon the volume of the fluid. These effects are readily studied by injecting non-irritating fluids into the heart sac of animals. With large volumes of fluid thus injected, the pressure outside the heart may be raised sufficiently to prevent the expansion of the heart, so that heart action practically ceases, death resulting almost instantaneously. Pus accumulation in the heart sac can be readily reproduced in animals, by injecting certain disease-producing microorganisms. With coagulated fluids in the heart sac there are often to-and-fro rubbing sounds produced between the heart muscle and the surrounding sac, sounds readily heard through a stethoscope.

"The fluid in the heart sac may be completely absorbed and the heart restored to normal. With pus accumulations, however, absorption is often slow and incomplete. The heart occasionally becomes permanently adherent to the surrounding sac, even growing fast to the structures outside the sac. Such adhesions cause serious mechanical interference with heart action. With each contraction of the heart, the heart pulls inward on the adherent parts, lifting the diaphragm, retracting the chest walls, pulling downward on the trachea. An adherent heart must do several times its usual work to maintain a normal circulation."

"A perfectly hopeless condition to treat," said the manufacturer.

"It is a good illustration of the sort of thing a physician is often up against. There is no therapeutic agent that can conceivably remove the scar tissue connecting the heart to the surrounding parts. Nor can these adhesions be influenced by direct mechanical agents such as massage. There are surgical ways, however, in which the handicap to heart action can be materially lessened. The main handicap of an adherent heart is the adhesion to semi-rigid structures such as the ribs and breast bone. Adhesions to elastic parts, such as the lungs and diaphragm, is a less serious mechanical embarrassment. Portions of the ribs and breast bone immediately over the heart can be removed surgically, leaving the heart covered only with elastic skin and underlying muscles. The heart is thus freed from its anchorage to rigid structures. This materially reduces the resistance it must overcome on contraction. This operation has been performed on numerous individuals with beneficial results."

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"Fluid accumulations also take place in the respiratory system. The simplest example is probably the accumulation of fluid outside the lungs in the chest cavity. The material so accumulated may vary from a clear water-like material to thick creamy pus. It may be mixed with varying amounts of blood. At times this pus may be coagulated or clotted to form a butter-like mass. The volume of the chest fluid may vary from a few drops to several quarts.

"The effects of such fluid accumulations are largely mechanical. With large volumes of fluid, parts of the lungs can no longer expand, so that respiration no longer takes place in these parts. On account of the generous oxygen surplus in the blood, however, this does not become a serious matter till over half of the lungs are thus thrown out of commission. With coagulated pus, to-and-fro rubbing sounds may be produced between the lungs and the chest wall, sounds readily heard with a stethoscope.

"On recovery, the fluid in the chest cavity may be completely absorbed and the lungs restored to normal. With coagulated exudates, however, the lungs often become permanently adherent to the chest wall. Probably the most unfortunate effect of such adhesion is the tendency of the scar tissue uniting the lungs and ribs to contract, pulling in on the ribs and hindering their movements. Marked deformities of the chest may result from this scar tissue."

"Can those adhesions be overcome surgically?" asked the lawyer.

"Operations within the chest cavity are very difficult. The usual treatment of such cases is to try to prevent deformities by systematic exercise. The deformity of the chest can be largely prevented by this means.

"In place of fluid, air occasionally accumulates in the chest cavity. This air may enter as a result of a wound in the chest wall. Or it may come from a ruptured or eroded bronchus. The lungs collapse more or less completely on the side of the chest containing the air. Blood passing through the collapsed portion of the lungs is no longer aerated. The resulting incomplete aeration of the blood does not endanger life. In fact, the artificial production of such partial collapse of the lungs by the injection of air into the chest cavity is occasionally resorted to as a therapeutic measure. Collapse favors the recovery of the lungs from certain local infections such as tuberculosis.

"Probably the most common fluid accumulation in the respiratory system is accumulation of pus in the lung itself. The pulmonary air sacs over large areas of the lungs may be completely

filled with pus. This is the condition known clinically as pneumonia. The pus very often coagulates in the air sacs. On healing, this semi-fluid material is usually completely absorbed or thrown out as expectoration. Occasionally, however, absorption is delayed, the air sacs eventually becoming permanently occluded with solid masses of scar tissue. This portion of the lungs is, therefore, permanently thrown out of commission."

"I thought pneumonia was an infectious disease," said the manufacturer.

"The pus accumulations in the lungs are usually caused by the presence of disease-producing microorganisms. If certain microorganisms are injected into the trachea of animals so that the microorganisms are drawn into the air sacs on inspiration, pneumonia results, practically identical with the pneumonia of human beings. Recovery from pneumonia comes only after these microorganisms have been killed or otherwise rendered harmless."

"Is there anything in this new serum treatment for pneumonia?" asked the manufacturer. "The papers were full of it a few months ago."

"I believe it would be best to postpone discussion of treatment till we have taken up the various biological forces in the human body, tending to prevent or to overcome disease."

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"Fluid accumulations are also common in the digestive organs and adjacent structures. Abscesses, for example, may form in almost any abdominal organ. They are particularly common in the appendix."

"I don't see the Divine wisdom of putting such a useless organ as the appendix in the human body," said the lawyer.

"The appendix is usually considered as a remnant of an organ that was of importance during the early evolutionary stages of the human race, but is no longer functionally active. Numerous other examples of apparently inactive ancestral remnants are present in the human body."

"Our Boston friend would consider it irreligious to imply that the human body is not perfectly designed to its present needs," said the lawyer.

"One of the most striking fluid accumulations in connection with the digestive organs is accumulation of fluid outside of the intestines within the abdominal cavity. Large volumes of clear fluid may thus form as a result of mechanical interferences with the circulation by a diseased liver. Equally large volumes of clear fluid

or of pus may accumulate as a result of the local action of disease-producing microorganisms. If certain disease-producing microorganisms are injected into the abdominal cavity of animals, the abdominal cavity becomes rapidly distended with pus, surrounding and bathing the intestines and pelvic organs.

"As soon as these microorganisms are killed by the defensive mechanisms of the body or otherwise rendered harmless, the accumulated pus is often completely absorbed, and the abdominal cavity restored to normal. Usually, however, temporary and often permanent adhesions take place. In extreme cases, all the organs of the abdominal cavity may be grown together in a solid mass.

"The formation of adhesions between abdominal organs may have very serious effects. Adhesions, for example, may be so situated as to interfere with the proper movements of the intestines, causing delay in the passage of food material. The adhesions may even completely close an intestine at one or more points, completely preventing food passage. Such intestinal stoppage, of course, will allow the stagnant food material to undergo fermentation and putrefaction. It will eventually cause death if not relieved by surgical means. In the same way, adhesions may compress the excreting ducts from the kidney, preventing the carrying off of liquid wastes from the body. Or they may surround the female reproductive glands, producing sterility.

"Accumulations of fluid or exudate may also take place within the digestive tubes. The most striking example of this is in Asiatic cholera. The microorganisms of this disease so irritate the intestinal lining that several quarts of fluid are often poured out into the intestinal canal. This fluid is usually expelled from the body, giving the characteristic watery discharge of cholera. The loss of fluid from the body is often so great that the body as a whole takes on a semi-mummy-like appearance. The blood becomes concentrated, changing to a viscid fluid of almost tar-like consistency."

"Is it true that whiskey is the only reliable cure for cholera?" asked the lawyer. "In a recent movie, the heroine contracted cholera. The hero dragged himself twenty miles with a broken leg to get her a bottle of whiskey. He thus saved her life."

"I have often wondered," replied the research worker, "why references to medical subjects in movies and in popular fiction are usually so out of accord with medical facts. The average screen physician is a brainless ass. He looks through the wrong end of a microscope and makes impossible cures. The physician of popular fiction is usually equally absurd. As a pure business proposition, a competent medical critic should be employed by every publisher."

6

"Accumulations of fluid also take place in the nervous system. A familiar example is hydrocephalus. The spinal cord, as you know, has a minute central drainage canal connected at the upper end with a series of drainage chambers in the brain. It occasionally happens that this drainage system is occluded, fluid accumulating, dilating the spinal cord or one or more chambers of the brain. This dilatation and distortion of the spinal cord usually gives sensory or motor disturbances. Dilation of the brain almost invariably causes mental deterioration.

"Another type of fluid accumulation in the nervous system is the accumulation of pus in the skull cavity immediately outside the brain. This is the characteristic picture of meningitis. The condition is readily reproduced in animals by injecting certain disease-producing microorganisms. Part of this pus can readily be withdrawn by inserting a large hypodermic needle into the spinal canal. This is often done for diagnostic purposes."

"Is such an operation dangerous?" asked the lawyer.

"Violent objection to this method of diagnosis was made in the earlier days. I believe the physician who first used this method was a professor in one of our big eastern medical schools. He stirred up such a rabid outcry against 'Vivisection of children' that he was requested to resign. This method of diagnosis is now used in all hospitals."

"We are about to cross Great Salt Lake," said the lawyer. "Let's adjourn to the observation car."

WHO PROFITS FROM SCIENTIFIC WORK?

By Dr. F. C. BROWN
BUREAU OF STANDARDS

SOME years ago a prominent American citizen said that he was not so much concerned with the advantages of the Twentieth Century Limited as he was concerned with who rode on the Twentieth Century Limited. He desired that this special service train should carry passengers who were rendering an increased service to the public by virtue of the increased speed and comfort rather than gamblers, bootleggers, criminals and those who merely flit for a living. We have spoken much of the great savings accomplished by the national Bureau of Standards and by standardization generally. We have shown that the scientific work of the Bureau of Standards has resulted in improved brake linings for automobiles, which work has resulted in a saving of $15,000,000 annually in the cost of brake linings. It is easy to understand that the average pedestrian as well as the automobile driver has a greater safety on the road as a result of better brake linings, but who gets the $15,000,000?

The question has particularly arisen with regard to the saving of wastes and losses resulting from the deletion of excess varieties, grades and sizes of commodities found in commerce. Manufacturers have recognized the enormous economic waste of excess varieties and are most cordial in the support of the Department of Commerce in cooperating to eliminate unnecessary lines of commodities. They have agreed to cut 66 miscellaneous sizes of paving bricks to five standard sizes in common demand. Similarly, asphalt for paving purposes has been cut from 102 to 10 varieties. Range boilers have been reduced from over 130 miscellaneous sizes to 13, brass traps from 1,114 to 72, hot water storage tanks from 120 to 14, hollow building tile from over 300 styles and weights to 19, wire fence from 552 to 69 varieties. Building materials, plumbing supplies and hardware are all being reduced to the minimum number of best standards that are known. A billion dollars may be saved to the country annually through this simplification work alone. With regard to the standardization and simplification of plumbing supplies, the president of the national association declared this to be the most important work being done by the national government and he felt prepared to support his declaration. Of course the manufacturers and jobbers in sheet metal will be pleased with the economies and savings effected by discontinuing nearly a thousand varieties and sizes, but how will the user of sheet metal profit?

This standardization of man-made things may be likened to what has taken place in the products of nature. Take corn, for example. Instead of letting every variety of corn grow as it will among weeds and other vegetation man has simplified the product. Not only is corn segregated from other vegetation, but the best standard of corn is selected and it alone is grown in a particular soil until man succeeds in producing a superior standard.

We have shown that as a result of the study of power loss in automobile tires there is to-day an annual saving of approximately $40,000,000 in gasoline consumption. In addition to this there is a large saving arising from the longer life of tires which are produced at less cost. We have spoken of the establishment of the dextrose industry and we have been willing to make the estimate that millions of dollars worth of the new product will be added to the country's resources. The Bureau of Standards has shown the gypsum industry a method of manufacturing a plastic gypsum. This discovery leads to better plastering at less cost than formerly. The mills are already producing this product. The saving in production and labor should run into hundreds of thousands of dollars annually.

Working with the Coast and Geodetic Survey the bureau has developed a new combination of radio and sound recording apparatus which will enable ships to locate their position near shore during foggy and unfavorable weather. This means that the survey ships will be able to work during all kinds of weather, thereby saving upward of a hundred thousand dollars. But this is insignificant compared with the value of the radio direction finder which was initiated by the Bureau of Standards and is being developed in cooperation with other government and commercial bodies. Within a few years there will be no such thing as holding up ships in navigation because of fog. Radio waves will generally replace the beacon light in time of fog as well as darkness. The saving in navigation costs will run into hundreds of millions annually. Likewise the bureau has developed a number of airplane instruments that have been adopted to meet the most exacting conditions. This work can not be evaluated, however, until the future has placed an eyaluation on air navigation.

Quite recently the bureau has developed a new safety release device for use on tanks containing compressed gases for shipment. This improvement will produce an estimated saving of $250,000 a year.

Very valuable contributions have been made to our knowledge of the materials used in huge structures. New strain gages have been devised to accomplish these results. The electrical strain gage, made of a pile of carbon discs, for the measurement of minute changes in the length of materials under varying loads, has already

been used in airships in flight, in bridge structures and in structural test members in the two million pound testing machine, and is now to be used further in road and bridge testing and in the study of the behavior of unusual dams and towers when the loads bring on the breaking point. It is difficult to place the value on an instrument which makes possible better and safer design of huge structures and which saves thereby both money and human lives, but it is easy to believe that the added information has a potential value of hundreds of millions.

In connection with building construction the work of the Building Code Committee, the Plumbing Committee and the Hardware Manufacturers Committee should save hundreds of millions annually in the construction of dwellings and offices. For example, the investigation showed the three-inch stack in plumbing to be equally satisfactory to the four-inch stack now in general use. This fact alone will save a million dollars annually in small dwellings. Likewise the investigation showing a petroleum product to be a satisfactory substitute for glycerine in door checks may mean an annual saving of $15,000. And so on we could relate how the investigation of paints, varnishes, soaps, metals, alloys, etc., all produce in one way or another enormous savings in American manufactured goods. Large savings have accrued in the production of government specifications in order that the government may get a uniformly good product for its money. One department this year saved $70,000 on the purchase of varnish as a result of these specifications Three men working for a year in the telephone section were able to cut the annual telephone bill in Washington by $85,000 without injuring the service. I believe that already the Bureau of Standards has played a key position in adding a billion dollars annually to the wealth of the nation. But suppose one institution does bring about such increased efficiency and these enormous savings in American manufacture, who gets the profit?

The scepticism on the part of some of the public, particularly those who may at some time or other have gone in for profit in oil wells or gold mines, is very well illustrated by the story told by the Iowa farmer who was about to buy cheaper land in Louisiana. He made the first trip from Iowa under the gentle guidance of the real estate promoter and was led to believe that the land was the equal of the Iowa land and was a bargain. It was disclosed that the land produced good crops of rice, cotton, sugar cane and even corn. In order not to act hastily and unwisely he went home and considered the proposition carefully with his wife. He then returned to the small town in Louisiana and proceeded to the farm in order to check his information with Jackson, the colored tenant on the farm. Jackson gave a very satisfactory report as to the

number of bales of cotton, the number of bushels of corn and other products, whereupon he continued his checking by asking Jackson if he did not have considerable money in his pockets as a result of these good crops. Jackson replied that he had no money at all and upon further questioning explained that "de ducks" had gotten everything. The Iowa farmer had heard of the chinch bug, the boll-weevil and the blackbird, but he had never heard of the duck pestilence. Finally Jackson explained that the crops were properly harvested and delivered to the store, but when he went to make settlement it was "de duck" so many dollars for flour, so much for ham, and "de duck" so much for this and that, and when the storekeeper was through there was only $7.87 left for Jackson. The average citizen of the land is very likely to wonder what is left for him out of the investment and profits from such institutions as the national Bureau of Standards.

It is a little difficult to show any particular citizen just where his share of the benefit comes, just as it is difficult to show him what good he gets from the army and navy, and even the post office, in case he does not happen to receive mail or the daily newspaper. In order to show what benefits have accrued to the average man we may well take a picture of the man a half century ago and compare this picture with the average man of to-day, not in his bank account alone but as to the privileges, comforts and safety that he enjoys. Happiness may be so difficult to evaluate that perhaps this were best omitted from the picture. The man who remembers fifty years ago or even less may picture the idle moments on the dry goods box, on the prairie schooner or at the fireside during the long winter evenings with pleasure or with agony. He may have appreciated an apparent lengthening of his life arising from the uneventfulness. To-day the average man has a telephone in his home. He may call up his neighbors or communicate with his relatives across the continent almost at a moment's notice. Formerly he could talk as far as his voice could carry and communicate as far as he could see his neighbor's light. To-day the average man can sit in his own home and hear talks from the most able men in the land. He can hear the finest music that only kings could hear formerly. Almost every man in the land travels in an automobile or in a train or even in an airplane if necessity or his heart's desire calls for it. This makes it possible for a man to cover as much territory in a year now as his ancestors covered in a lifetime. The big earth has apparently shrunk or, looking at it in another way, man has grown in his power so that the earth seems small relatively. The average man gets a very excellent picture of great actors on the movie screen and he enjoys these more frequently and more intently than kings and princes enjoyed the depicting of human life on the stage a century ago. A half century ago the great musicians were heard only

by a relatively small number of people. To-day they are heard not only over the radio, but their accomplishments are recorded in wax and reproduced quite faithfully for all time to come. In a sense greatness has become immortalized. In those days, when only a few could hear and see the prima donnas, only about the same number could wear silk gowns and silk stockings. To-day the number without silk stockings are as rare as those with them a half century ago.

In this half century period we have seen the great developments and additions to man's comforts and power through electricity. We have the street car, the automobile, the elevator and many other inventions carrying man or his possessions by electricity. We have electricity stored up in countless batteries ready to do man's work, starting his automobiles, controlling his railway safety switch signals, furnishing power for his radio and so on. Countless electrical motors render service to every man, either in street cars, elevators, factory machinery, washing machinery, vacuum cleaners or what not. But perhaps the greatest of all is the electric light, which nearly every citizen of the land can enjoy. Likewise every one can cook his meals with gas. Millions to-day have their noon-day meals in cafeterias, lunch rooms and palaces as compared with the cold lunch in a dinner pail less than a quarter of a century back.

A half century ago art was limited to a very few. Aside from the natural beauty of the hills and trees there was not much beauty for the average man. The benefits from improved and more efficient architecture such as we now have in our homes and public buildings, as well as the more pleasing effect in improved landscape gardening, are immeasurable. No value can be placed on increased happiness arising from a more universal appearance of well-dressed folks, beautiful buildings and interior decorations of homes and handsome public conveyances.

In the matter of public health and sanitation the figures show a very great diminution in the death-rate. We can hardly guess as to the amount or the value of the easement of our nerves arising from such blessings as the intelligently controlled water supply, improved machinery, improved surgical apparatus, discoveries in X-rays and radium and the broader knowledge of the properties of matter generally, which have all contributed to practically eliminate plagues, pestilences and the like, and have almost gone so far as to cure incurables.

The man of yore quite frequently had to sleep with his gun over the doorway or under his pillow. To-day a man feels safe to live and travel anywhere without a weapon for defense. Institutions of many varieties make hunger and suffering in old age quite unusual. Over a hundred billion dollars in life and fire insurance

goes far to relieve human nerves from worry and to raise the level of human output.

Every sense that man possesses has been expanded as a result of scientific effort in our civilization. Our increased knowledge about the properties of matter and energy and the commodities of commerce has enormously increased the power of the average man.

With this rough picture of what scientific achievement has added to human comfort, safety and ease of living, there is not left much room for doubt as to who gets the benefit from improvements and savings in the manufacture and distribution of the articles of commerce. When we enter the millionaire's estate and see his well-groomed and well-fed servants, we are led to believe that every one on the payroll is in improved circumstances because of the millionaire's success. Perhaps we wonder after all if he does give an equitable distribution of his wealth in proportion to the worthy efforts of those who help him

Consider automobile brake linings as an example The manufacturers are placing a product on the market from three to seven times as good as that three years ago for practically the same cost. I believe that in the severe competition that exists in the automotive industry this saving is handed down to every buyer of an automobile. This means that only one third as many men need be engaged in making automobile brake linings. In other words, these additional men are released to help society in other ways, to develop or raise new agricultural products, to manufacture cosmetics, to discover new wonders of the world or what not. Quite aside from economic considerations there is the advantage of greater human safety. A very large portion of the accidents and deaths from automobiles in recent years have arisen because brake linings were worn so that the driver did not have proper control of the machine. Every improvement in brakes saves the lives of many people.

With regard to the automobile tire, it is common knowledge that the tires are more than twice as good as they were a few years back, and the price is less I would not go so far as to ascribe a keen desire on the part of any manufacturer to reduce prices voluntarily. It is rather the fundamental and classical law of economics that has prevailed Competition has led the tire manufacturers to make a better product and to use all the scientific information available from the Bureau of Standards or where not. Improvement in quality and reduction of waste has been stock in hand. The prices have been fixed and lowered in order to get business and maintain profits. The fact is, the rewards of science as applied to automobile tires have certainly been handed down to every automobile owner and to every man who is rendered service by the automobile.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

COTTON FINDS A NEW CAMOUFLAGE

COTTON is a social climber. Handicapped by its lack of the sheen of silk or the luster of linen or the warmth of wool, it is now gaining upon its rivals by aid of the chemist.

Silk, the aristocrat of textiles, gets the gloss that is the envy of the rival fibers from being forced out in a viscous form from the tiny orifices of the spinnerets of the silkworm, solidifying as a single slick smooth cylinder a thousand yards long.

Cotton, on the contrary, if you compare it under a microscope, looks like a short twisted tape, and wool like a rough and scaly rope. Cotton, to quote an old joke, shrinks from soaping—like a small boy Dipping cotton into strong alkali causes the fibers to shorten and thicken and soften Seventy-five years ago it occurred to an English chemist, John Mercer, to try what would happen if the cotton were not allowed to shrink. So he kept the thread or cloth on stretchers while it was dipped into a solution of caustic soda and left to dry under tension. The lye took the kinks out of the cotton and softened its surface and this gave it something of the luster of silk. So Mercer immortalized himself, like J L. MacAdam, the road-maker, by converting his name from a proper noun to a verb, and we have had "mercerized" cotton ever since.

Now a new method of treating cotton has been invented. This is the opposite of the mercerization process for it is produced by acid instead of alkali. Charles Schwartz, of the Philana Company, at Basle, Switzerland, has found that cotton may be made to resemble its other rival, wool, by immersing it in concentrated nitric acid. The fibers become more curly and their surface rougher, and the fabric assumes the texture of a new material to sight and touch. The tensile strength is said to be increased by fifty per cent. and the resistance of the surface against scraping to be improved by two hundred per cent. In wear and warmth and appearance the philanized cloth resembles woolen.

We might suppose that the action of nitric acid on cotton would produce nitro-cellulose, otherwise known as gun-cotton. It would not be pleasant to go about clothed in a high explosive. But in making nitrocellulose sulfuric acid is needed to facilitate the reaction of the nitric. In the present process the nitric acid merely attacks the surface and is all washed out afterwards, or eliminated by alkali. The cotton acquires a yellowish tinge but this may be removed by bleaching. The philanized fabric may be later mercerized and this makes it look like linen. It is said to dye more readily and brilliantly than untreated cotton. One of the leading German dye works is using the new process.

In England nitric acid is being applied to the improvement of ramie, an Indian fiber. When ramie under tension is treated with nitric acid, it acquires a silken luster. When not stretched, it resembles wool. Three minutes' dipping in the cold concentrated nitric acid is sufficient for the

LORD LISTER

Unveiling of the statue of Lord Lister in Kelvingrove Park, Glasgow, on September 17. Lister became professor of surgery in the University of Glasgow in 1860. He began to develop his antiseptic treatment of wounds in 1865.

effect. The fiber gains slightly in weight and considerably in strength and takes dyes better.

The chemist has made a new market for cotton waste by dissolving it completely in nitric acid, alkaline sulfide or acetic acid, and spinning out the viscous fluid into threads of any length, size and shape that he pleases, producing thereby a synthetic fiber that closely simulates silk in appearance if not in strength. Fifty per cent. of what seems to be silk now-a-days comes from the chemical laboratory instead of from the cocoon. By taking on the chemist as an ally, King Cotton is enlarging his realm.

IS IT MOONSHINE?

A COUPLE of years ago an Englishwoman, Miss Elizabeth S. Semmens, was told by an old gardener that seeds planted in the first quarter of the moon germinated better than when planted in the dark of the moon.

Being a scientist as well as a woman, Miss Semmens was endowed with a double dose of curiosity, so she set herself to find out, first, if it were so, and second, if so, why?

Miss Semmens began by exposing different samples of the same seed to moonlight and to sunlight, and she found that more seeds germinated in the moonlit set than in the sunlit set. This indicated that there might be something in the old idea. Anyhow it seemed worth investigating more closely.

At first thought the notion seemed absurd, for moonlight is half a million times weaker than sunlight so how could it be more effective in stimulating plant growth? Besides, moonlight is sunlight, for the moon shines only by the reflected rays of the sun. Has the sunlight undergone any change in quality by being reflected from the moon besides being diminished in quantity? In one respect it has, though nobody ever thought it made any difference. Reflected light is polarized. Light consists of vibrations across the line of sight. If we look at a lamp on the other side of the room, the light waves in the ray coming to us move up and down, right and left, and all the angles in between. But if the ray of light is reflected in a mirror at a certain angle, part of the vibrations, say the sidewise movements, are quenched and the ray of reflected light consists mostly of vibrations in one plane, say up and down. Such light is called polarized because the vibrations have polarity, that is, motion to and fro in one line of direction. The eye can not tell the difference between polarized and ordinary light, and we do not like to think that plants are brighter than we are in any respect.

But we have to admit that there are some things that a plant can do and we can not. One of them is the building up of starch out of glucose which the plant accomplishes with ease, but which we are not yet wise enough to do. The reverse process, the breaking down of starch, we can do and do do in our glucose factories, where thousands of tons of cornstarch are turned into syrup. This is accomplished in the factory by soaking the starch in warm water and adding a little acid. The plant gets the same result by using, instead of acid, a minute amount of a ferment called diastase.

In order to see if polarized light had any effect upon the digestive processes of the plant, Miss Semmens placed some grains of starch in a weak solution of diastase on a microscope slide and threw upon it a beam of polarized light, using a mirror instead of the moon for reflecting the ray because it is handier to handle. Another slide of the same sort was ex-

posed to ordinary diffused sunlight, mostly not polarized, and a third was kept in the dark. The starch was actively attacked and dissolved under polarized light; very slowly in the ordinary sunlight, and not at all in the dark. The temperature was kept the same for all three slides, too low a temperature for the starch to dissolve under ordinary conditions. In some cases artificial light was substituted for daylight, and the light was either polarized by reflection from a glass-covered ferrotype plate or by passing it through a Nicol prism, which consists of a calcite crystal cut in such a way as to divide a ray of ordinary light into two rays, polarized at right angles to each other.

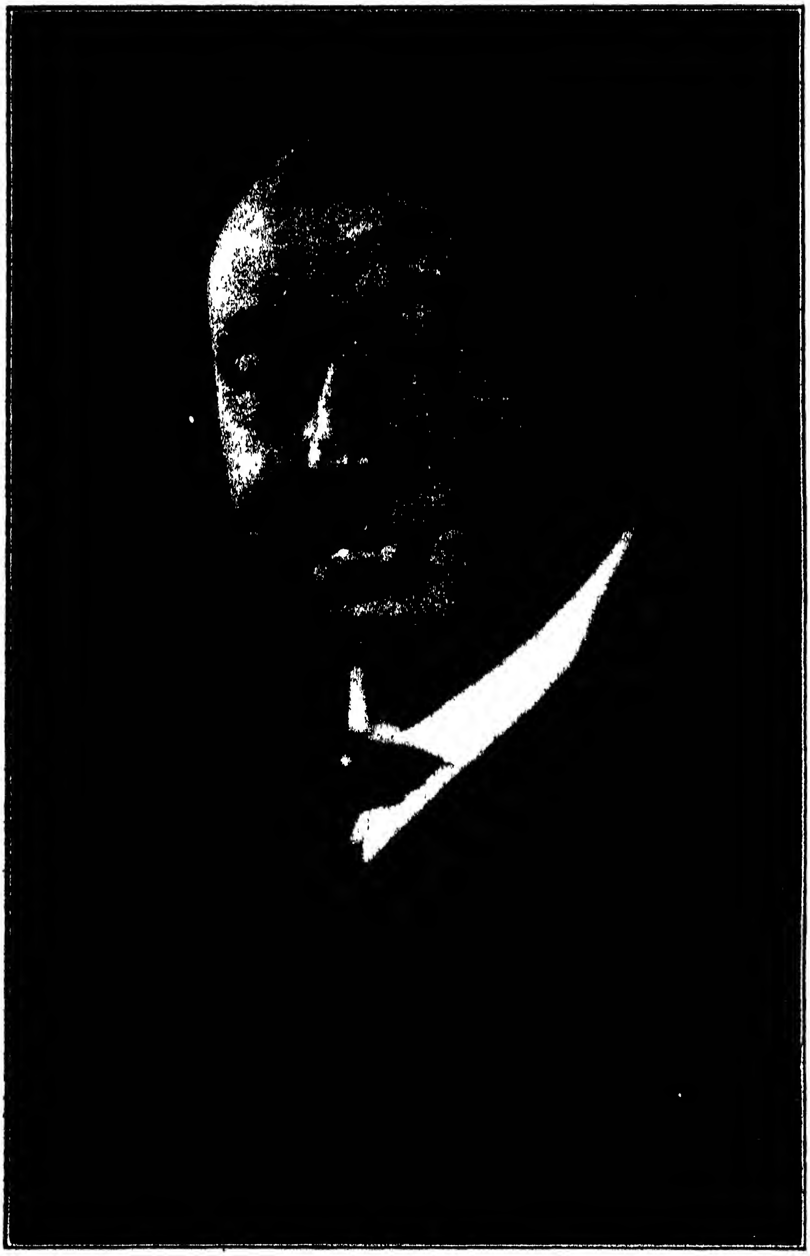
Miss Semmens showed me some of her photographs and slides on a train in Canada last month. Where the polarized light had been at work for awhile the purple starch grains disappear and appear in later slides as coppery spots of glucose very plain and very pretty. A starch grain seen through a microscope looks like a big clam shell. Those that were being eaten away by the diastase under polarized light were notched and nicked all around the edge, like a cake that had been nibbled at by a small boy.

When Miss Semmens announced her results, they were received with much surprise and considerable skepticism. Nobody had ever seen such an effect by polarized light Which is not strange, considering that nobody ever seems to have looked for it. Also, it was pointed out, the experiments were delicate, the results microscopic and the liability of error great. And finally, what reason was there for thinking that the reactions observed under the microscope actually occurred in the plant.

But Miss Semmens--well, you know how women are, the more you tell them that they are wrong the more apt they are to prove themselves right. In spite of the incredulity of experts, she went on with her work. She obtained funds for research from her college, Bedford College for Women in London. She made a convert to her views in Professor Baly, of Liverpool University, who has been carrying on remarkable researches in the synthesis of sugars by electric light, and she went to Liverpool to work with him. Then she crossed the Atlantic to continue her experiments under Professor Lloyd, of McGill University, Montreal.

She has now proved that polarized light thrown upon a living leaf will stimulate the dissolution of starch grains just as it does on a glass slide. Now when the insoluble starch molecule breaks up it splits into two molecules of glucose. Increasing the number of molecules in the cell sap must cause an increase in the solution pressure and so a swelling of the cells. The mouths through which the plant breathes, the stomata of the leaf, are closed and opened by two guard cells which act like lips. When these swell and stiffen the mouth closes. These guard cells are filled with starch and when this breaks down into sugar the cells become turgid and so open the slit. Miss Semmens has found that polarized light has this effect and so may account for the opening and closing of the stomata as the daylight changes.

Just before sunrise, and after sunset, the light we get is largely polarized since it comes to us by reflection from particles in the air. As the sun rises to the noon height, the proportion of direct light becomes greater and of polarized light less. This is the time when starch is formed in the green leaves by the sunshine, but after six o'clock, when the vertical light from the evening sky striking the leaves is polarized, the starch begins to dissolve into glucose.



DR. HARVEY W. WILEY

The distinguished agricultural and food chemist, from 1883 to 1912 chief chemist of U. S. Department of Agriculture and for many years professor in George Washington University, whose eightieth birthday was celebrated on October 18.

DR. H. W. WILEY'S

It is a new field into which Miss Semmens has entered and if her results stand the test of further investigations they may give a clew to many a problem of plant and animal life. She herself regards the question as still in the tentative stage and, while she is confident of the validity of her experiments, she religiously resists the temptation to speculate as to their possibilities, at least in public.

It would be foolish of me to rush in where she fears to tread, but I can

COMPLETE WORKS

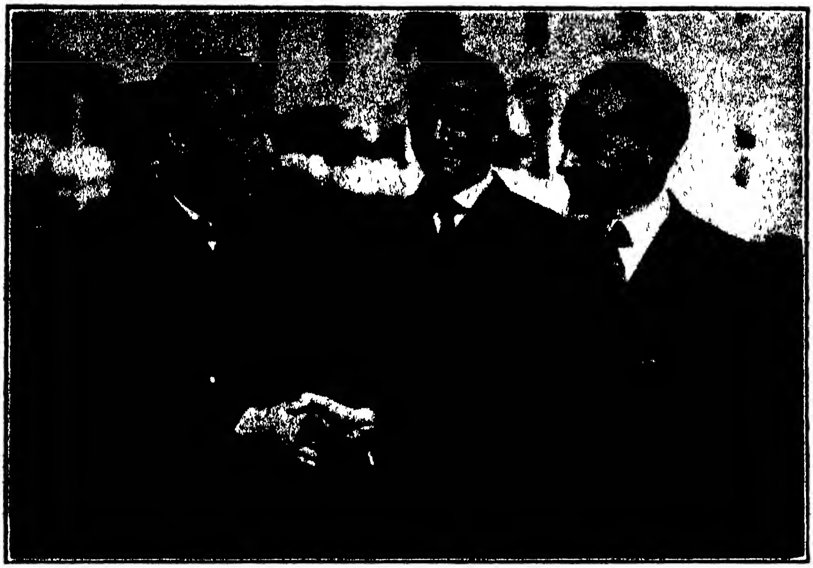
not refrain from calling attention to the importance of polarization in vital processes. It is well known that many of the substances found in plants and animals, notably starch and sugar of all sorts, have the peculiar power of twisting around a ray of polarized light as it passes through them. They are, as the chemist calls it, "optically active." The molecule is so constructed as to have a sort of corkscrew action on such light. This peculiarity is taken advantage of in sugar analysis. When the chemist wants to find out how much sugar a beet contains he simply squeezes out

THE SHENANDOAH

Photographed from a navy airplane while passing over Los Angeles.

THE GIANT ZEPPELIN, ZR 3

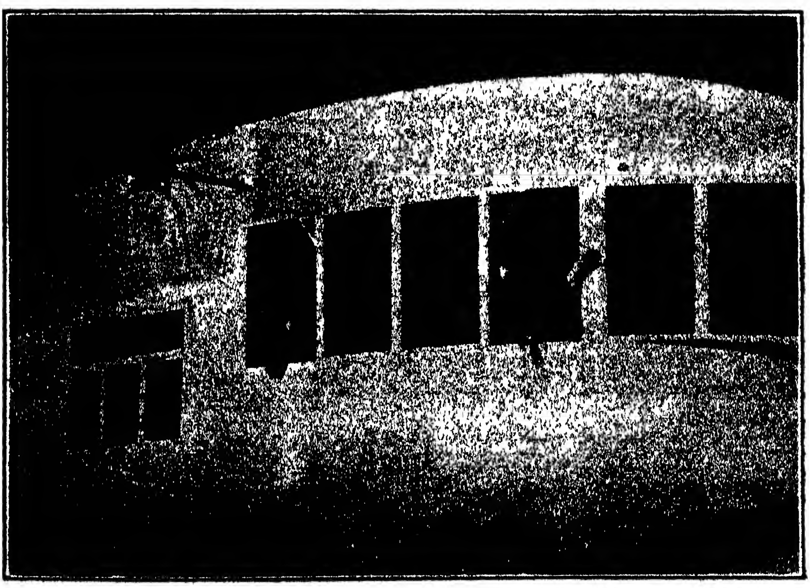
Photographed as she was arriving at the Naval Air Station at Lakehurst, New Jersey, after her eighty-one hour voyage across the Atlantic.



PRESIDENT COOLIDGE GREETING OFFICERS OF THE DIRIGIBLE ZR 3

On the left is Dr Hugo Eckener, German commander who had charge during the flight to the United States; next to him is Capt. E A. Lehmann, assistant to Dr. Eckener.

Henry Miller News Picture Service, Inc



CABIN OF THE GIANT ZEPPELIN, ZR-3

Photographed as she was arriving at the Naval Air Station at Lakehurst.

the juice and puts it into a tube of known length, capped with glass at both ends, looks at a ray of polarized light passing through it, and reads off the percentage of sugar. Some sugars rotate the ray to the right, others to the left, in different degrees but always the same for each sugar. The right and left screw-forms of the same substance often have different physiological effects. Certain kinds of bacteria will eat a left-handed compound while rejecting its right-handed twin. But when a chemist makes one of these vegetable compounds artificially, it usually turns out to be inactive because the two opposing forms are mixed or combined so as to neutralize each other. Since so many natural substances have an effect on polarized light, it would not be surprising after all if it should be found that polarized light had an effect on them.

Then there is reopened the question of the moon which in all ages has been supposed to exert a mysterious influence upon—but I really must stop lest I wander beyond the legitimate range of the scientific imagination.

FEELING THE PULSE OF A STAR

By a new method of analyzing the spectrum of a star, it is now possible to trace regular pulsations through its atmosphere. What caused the fluctuations in the intensity and quality of the light from variable stars has long been a puzzle to astronomers.

By comparing the swinging of a candelabrum with his own pulse beats, Galileo discovered that the period of a pendulum is constant, that is, it does not depend upon the distance through which it swings. Quite similarly the gases in the atmosphere of a variable star are swinging back and forth, in and out, all in the same length of time, but not all through the same distance, as the outermost layer in some of the stars moves very little. Moreover, one layer of the atmosphere receives the motion and passes it on to the next from interior to exterior and back again like a perpetual motion machine. The pulsation of the outer layer takes place last, just as the tipping of the last domino of a falling row; but to make the analogy complete someone would have to stand the dominoes on end again and start the motion backward.

The pulse of the giant star, Eta Aquilae, beats once a week and during this period the star changes from the third to the fourth magnitude, which is easily observed with the naked eye. The change of light accompanies the pulsation through the atmosphere, which carries the energy from the storehouse in the interior to the surface boundary for exportation. During the same time the star changes from a bright orange to a golden color with the increase of radiation.

The cause of these changes has been investigated at the Observatory of the University of Michigan by Professor W. Carl Rufus. By employing a new method of analyzing the rays from this star he has found that the changes of its light are due to alternate compression and expansion of the atmospheric gases.

Compression is a heating process, and the increase of temperature of the radiating surface makes the star shine more brightly. Expansion produces the opposite effect. So with every beat of the pulse of the star these alternating physical processes are revealed in the rate of flow of its energy as seen by the eye and interpreted by the mind of man.

The source of this inexhaustible supply of energy, however, is a problem that has completely baffled the astronomers in spite of their giant telescopes, their ingenious spectroscopes and sensitive photometers. Energy seems to be a final product in the quest for scientific truth or the most primitive star-stuff from which the universe evolved.

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